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Draft A

Groundwater/Vadose Zone Integration Project

System Assessment Capability (Revision 0)

Assessment Description, Requirements, Software Design, and Test Plan

Prepared for the U.S. Department of Energy, Richland Operations Office
Office of Environmental Restoration

Submitted by: Bechtel Hanford, Inc.

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EXECUTIVE SUMMARY

This report describes computational tools and assessment plans for the initial assessment of the Hanford Site's present and post-closure cumulative and composite effects of radioactive and chemical materials that have accumulated since 1943. The computational tools and supporting data are known as the System Assessment Capability (SAC).

The task of predicting the migration and fate of contaminants that were discharged or disposed (and will remain at the Hanford Site), and estimating the impact of those contaminants, is challenging. As a result, the capability will be developed in several iterations to focus available resources on the components of the system that significantly contribute to risk and to ensure that users have the opportunity to view results at intermediate stages in the development. Users include Hanford projects, the U.S. Department of Energy, regulators, stakeholders, and Tribal Nations. This document presents the planned analyses for the initial assessment and the software requirements, software design, and software test plan for the initial SAC (also called SAC Rev. 0).

Section 1.0 provides background information on the SAC. Section 2.0 outlines the purpose of the SAC and this document. Section 3.0 describes the initial assessment to be performed using the new computational tools. Section 4.0 describes the software requirements for the computational tools supporting the initial assessment. Section 5.0 describes the design of the SAC (Rev. 0) computer codes. The design overview includes the major information exchanges between modules. Knowledge of the information to be passed between computational modules is essential to understand constraints on the system architecture, platform, and data management. Section 6.0 provides a high-level description of test cases to be used to verify proper performance of the SAC (Rev. 0) computer codes.

The initial assessment description focuses on the future state of the Hanford Site, the physical processes governing release and transport of contaminants, and the exposure scenarios to be modeled. Simulation results will start with contaminant inventory, and continue through waste form release, vadose, and groundwater-based transport, and movement in the Columbia River.

The SAC (Rev. 0) will indicate the distribution of contaminants at selected moments in time and at selected locations. The SAC will use these contaminant distributions to estimate risks and impacts to human and ecological health, cultures, and the regional economy through a suite of exposure scenarios.

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ACRONYMS

CERCLA	*Comprehensive Environmental Response, Compensation and Liability Act of 1980*
CRCIA	Columbia River Comprehensive Impact Assessment
DOE	U.S. Department of Energy
ECDA	Environmental Concentration Data Accumulator
ECEM	Ecological Chemical Exposure Model
EIS	Environmental Impact Statement
ERDF	Environmental Restoration Disposal Facility
ESD	Environmental Settings Definition
ESP	Environmental Stochastic Preprocessor
GW/VZ	Groundwater/Vadose Zone
HCP	Hanford Comprehensive Land Use Plan
HSDB	Hanford Site Disposition Baseline
ILAW	immobilized low-activity waste
LOAEL	lowest observed adverse effect level
PFP	Plutonium Finishing Plant
SAC	Systems Assessment Capability
SNM	special nuclear material

1.0 INTRODUCTION

The Groundwater/Vadose Zone (GW/VZ) Integration Project is currently developing the tools and supporting data to assess the cumulative impact to human and ecological health and the region's economy and cultures from waste that will remain at the Hanford Site after the site closes. This collection of tools and data are known as the System Assessment Capability (SAC). This report describes the application, requirements, and software design of the SAC.

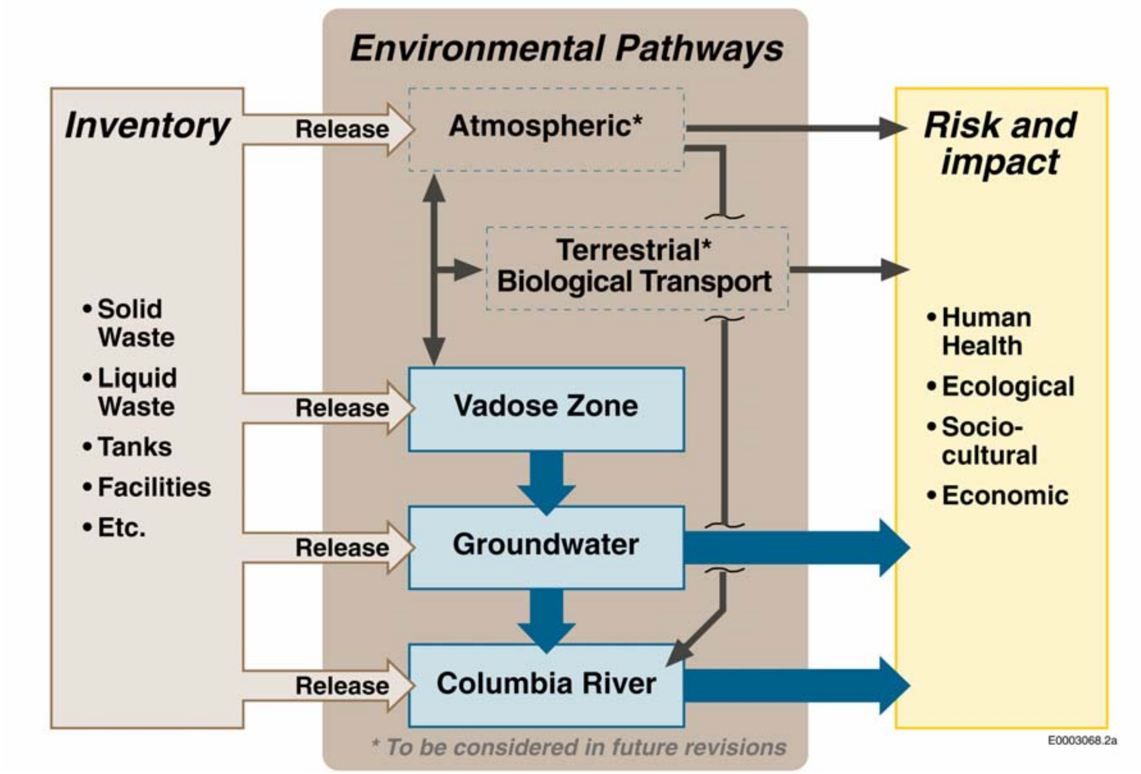
The SAC (Rev. 0) is being designed as a relatively simple demonstration capability. Figure 1-1 is a conceptual illustration of the technical elements important to the assessment. Computational tools or descriptive approaches are being developed to represent each technical element included in the SAC (Rev. 0). Data relevant to the Hanford Site for each technical element will also be brought together to support the respective computational tool so that the movement of contaminants through the environment and their impact can be estimated.

The conceptual illustration of the SAC portrays a linear flow of information. In general, inventory feeds to release, feeds to vadose zone, feeds to groundwater, and feeds to the Columbia River. Release occurred, at times, to the groundwater through reverse wells and to the Columbia River from the single pass reactors. The Columbia River includes the groundwater/river interface, river flow and transport, and biological transport. The groundwater and Columbia River technical elements provide media-specific concentration estimates used in the risk and impact assessment. Figure 1-1 notes the omission of the atmospheric and terrestrial biological transport pathways in the SAC (Rev. 0). The atmospheric pathway is omitted because of its relatively small contribution to contaminant migration in a post-closure setting when waste forms and disposals are stable. Terrestrial biological transport would quantify the biological migration and fate of contamination at the soil-atmosphere interface. The inclusion of feedback and atmospheric and terrestrial biological transport pathways will be considered during the design of future revisions to the SAC. These future revisions will occur during fiscal year 2002 and beyond.

One of the challenges associated with performing an assessment is appropriately presenting how well the results predict what might actually occur. This is because the attributes of the site that effect transport of contaminants, the impact of contaminants on living systems and the future conditions used in the assessment, as well as many other factors upon which the predictions depend, are not completely understood. The tools and data sets being assembled, and the planned assessment, will attempt to estimate the uncertainty in the results due to many of these factors. Where uncertainty is not incorporated in the calculations, it will be described along with the quantitative results.

The task of predicting the migration and fate of contaminants that were discharged or disposed (and will remain at the Hanford Site), and estimating the impact of those contaminants, is challenging. As a result of the system complexity, the SAC will be developed in several iterations to focus available resources on the components of the system that significantly contribute to risk. An iterative approach will ensure that users, including regulators, Tribal Nations, and stakeholders have the opportunity to view results at intermediate stages in the development. This will allow the users to influence the design of the final capability.

Figure 1-1. Conceptual Model of the System Assessment Capability.



This document presents the planned analyses for the initial assessment and the software requirements, software design, and software test plan for the initial SAC (also called SAC Rev. 0). The planned assessment will be completed during fiscal year 2001.

Background information for the development of the initial SAC is presented in *Groundwater/Vadose Zone Integration Project: Preliminary System Assessment Capability Concepts for Architecture, Platform and Data Management* (BHI 1999), which can be found at http://www.bhi-erc.com/vadose/sac.htm#Info. This document includes a description of alternate architectures for the SAC, as well as conceptual models for each technical element of the capability.

2.0 PURPOSE

This document presents a description of the initial assessment and a description of the computational tools of the SAC (Rev. 0). The SAC (Rev. 0) computational tools and data, and the assessment to be performed, are being designed to demonstrate that an assessment of the scale and scope of the Hanford Site and the Columbia River can be conducted. The assessment is expected to yield information and insights about the migration and fate of Hanford Site contaminants, as well as information needed to design and build an improved assessment capability. While the initial effort will be limited in some respects, it is being designed to:

- Examine radioactive and hazardous chemical contaminants that are expected to be dominant and representative contributors to risk and impacts.
- Determine the long-term (i.e., 1,000-year post-closure period) migration and fate of dominant and representative contaminants in the Hanford Site operational areas (i.e., 100, 200, and 300 Areas).
- Include a quantification of uncertainty (e.g., both conceptual model, and parametric).
- Include a suite of quantitative and qualitative risk and impact metrics.

A subset of dominant and representative contaminants will be investigated in the planned effort. Current plans call for the study of several radionuclides (see Table 2-1). A greater number and variety of radionuclides and chemicals will be studied in future assessments to better understand the potential impacts to human and ecological health, the regional economy, and cultures.

The process leading toward the development of this capability has identified several important additional features that have significantly influenced the design. Those features include the need to:

- Develop a holistic inventory
- Generate forecasts of groundwater contaminant plumes
- Quantify the effects of contaminants on human health and resources of concern
- Build a capability that could be used or improved upon to meet the requirements of U.S. Department of Energy (DOE) Order 435.1 on radioactive waste management.

Table 2-1. Selected Radionuclides to be Evaluated in the SAC (Rev. 0) and the Rationale for Selection.

Radionuclides and Chemicals Included in the Initial Assessment	Rationale for Selection
Tritium, technetium-99	Both potentially significant dose/risk contributors: tritium for present day; technetium-99 for future. Both are highly mobile; field data exist for history matching.
Iodine-129, uranium-238	Both are significant potential dose/risk contributors. Both are generally observed to be moderately mobile at the Hanford Site.
Strontium-90, cesium-137	Significant quantities of these two fission products were generated and remain at the Hanford Site. They are generally observed to be less mobile than tritium, technetium-99, or iodine-129 in the Hanford Site sediments.
Plutonium-239/240	Plutonium-239/240 have relatively long half-lives. Plutonium is a potential health risk if mobile.
Carbon tetrachloride	The largest chemical plume underlying the 200 West Area, except nitrate.
Chromium	Among the most significant chemical plumes in the 100 Areas.
Total uranium	Uranium included as a human health risk (i.e., toxin to kidney).

The overall purpose of the SAC (Rev. 0) is a demonstration that an assessment on the scale of the Hanford Site is achievable. Accordingly, the SAC (Rev. 0) computational tools will be successfully demonstrated if they execute the problem as described and sized in the software requirements chapter. It will be judged as very successful if the execution time goal of 30 days is achieved (see Section 4.7) for the 1,000-year simulation of 100 realizations and 10 contaminants.

The credibility of any analysis of environmental consequence and risk begins with the inventory being analyzed. In many cases, especially when isolated wastes or events are analyzed, a conservative or bounding estimate of inventory is satisfactory. For a sitewide analysis of cumulative impact, and especially for an uncertainty analysis, the inventory must be viewed and analyzed from a mass balance or holistic viewpoint. The total amount of waste represented in various forms in the assessment must be equal to the total amount of waste imported to the site or generated on site. Of course, radioactive decay and waste exports must be considered. If the mass of contaminant in one waste form increases in a scenario, the mass in other waste forms must decrease so that the total mass represented in the scenario is consistent with this total.

The ability to generate forecasts of groundwater plumes provides information necessary to assess cultural impact. The groundwater simulation also predicts contaminant flux into the Columbia River. This capability will allow history matching between predicted contaminant distributions in groundwater and the distributions observed (to date) through groundwater monitoring at the Hanford Site. The capability to forecast flux to the river will enable comparisons to prior estimates of Columbia River contaminant levels and mass flux. The need to generate plumes requires the use of a two-dimensional or three-dimensional groundwater flow and contaminant transport model.

The ability to quantify effects on human health and resources of concern on the basis of predicted contaminant concentrations at specific locations will result in a more comprehensive and less conservative assessment of impacts than has previously been performed. With this capability, DOE will be able to go beyond screening-level studies and estimate effects under realistic exposure conditions. In addition, DOE will be able to address primary impacts (e.g., health of individual organisms), as well as secondary impacts (e.g., effects on the region's economy). Again, this need requires the use of a two-dimensional or three-dimensional groundwater and river flow and contaminant transport model in the tool.

The SAC (Rev. 0) must build toward a capability that will meet the requirements of DOE Order 435.1 as a matter of efficiency. This DOE order requires that an estimate be made of the cumulative radiological impacts from active and planned low-level radioactive waste disposal sources and other potentially interacting radioactive waste disposal sources that will remain following site closure. The SAC will be used to perform future assessments to meet the requirements of this order. The cumulative impact assessment will complement the site-specific and individual waste impact analyses conducted in support of DOE Order 435.1, (i.e., performance assessments), the *Comprehensive Environmental Response, Compensation and Liability Act of 1980* (CERCLA) (i.e., Remedial Investigation/Feasibility Studies), and the *Resource Conservation and Recovery Act of 1976* (RCRA) (i.e., RCRA Facility Investigation/Corrective Measure Studies).

This document describes computational tools and assessment plans for the initial demonstration of the SAC. Section 3.0 of this document describes the initial assessment to be performed using the assembled computational tools. Section 4.0 describes the software requirements for the computational tools included in the capability. Section 5.0 briefly describes the design of the computer codes being assembled or developed to meet those requirements. The design overview includes the major information exchanges between modules. Knowledge of the information to be passed between computational modules is essential to understand constraints on the system architecture, platform, and data management. Section 6.0 describes test cases to be used to evaluate whether the computer codes perform as expected. Appendices provide previously unpublished mathematical formulations for the ecological and economics module, a summary of the requirements to perform the uncertainty analysis, and a glossary.

3.0 ANALYSIS PLAN FOR THE INITIAL SYSTEM ASSESSMENT

Once assembled and tested, the SAC (Rev. 0) will be applied to perform a sitewide assessment. This section of the assessment design document describes that initial assessment, the required analysis. This section summarizes the major assumptions governing the analysis, and describes the analysis to be performed by each assessment module. This section begins with a brief description of the Hanford Site and the past and present missions of the Hanford Site. The overview discusses the site cleanup scenario to be analyzed, the contaminants to be traced to risk and impact, and the overall climate, reservoir operation, and background contamination assumptions governing the long-term aquifer and Columbia River system.

3.1 THE HANFORD SITE

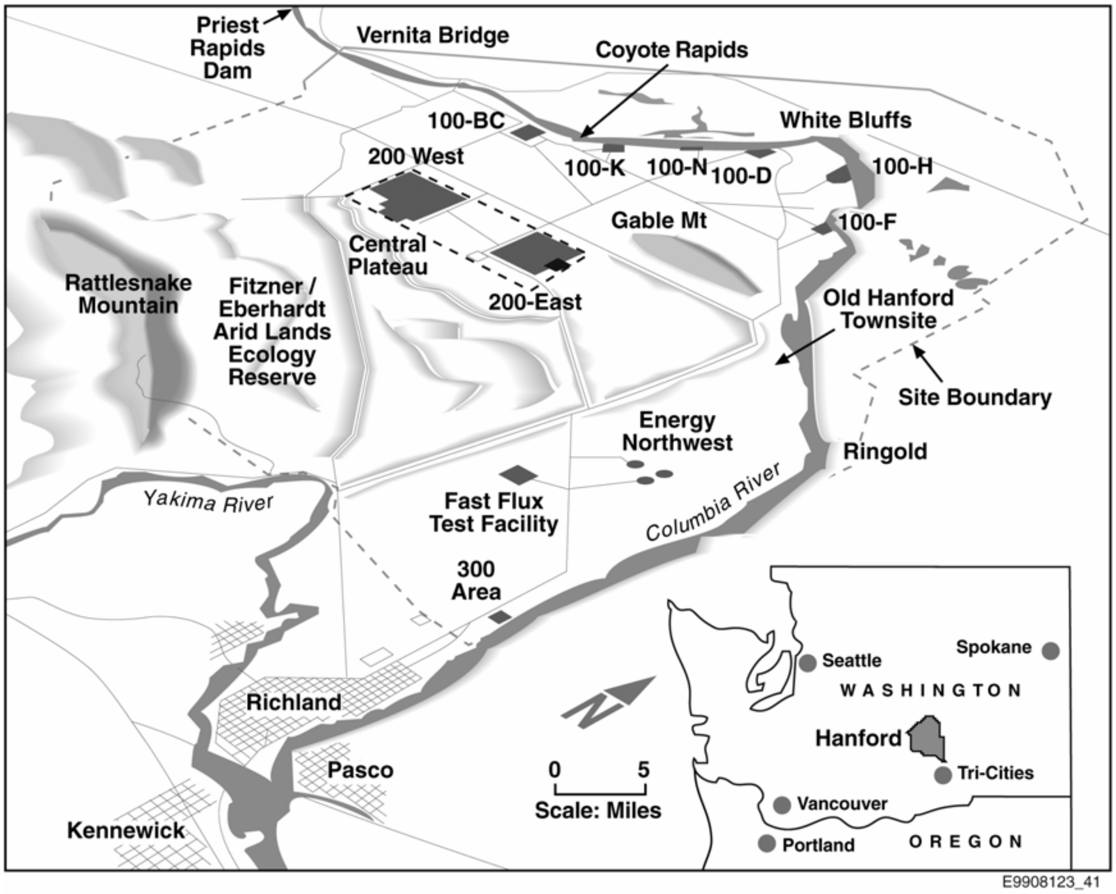
The Hanford Site lies within the semi-arid Pasco Basin of the Columbia Plateau, in southeastern Washington State (Figure 1-1 [Gephart and Lundgren 1995]). The Hanford Site occupies approximately 1,450 km^2 (560 mi^2) and is located north of the city of Richland, Washington. About 6% of the land area has been disturbed and is actively used. The Hanford Site is located upstream of the confluence of the Yakima and Snake Rivers with the Columbia River, approximately 40 km (25 mi) north and upstream of the Oregon border. A dry area known for its sandy soils, basalt ridges, and shrub-steppe vegetation, the Hanford Site is bordered by the Columbia River on the north and east. The Yakima River flows near a portion of the southern boundary of the Hanford Site before it joins the Columbia River south of the city of Richland.

A complete description of the Hanford Site can be found in an annual report on the environment (Dirkes et al. 1999). Unconfined and confined aquifers underlie the Hanford Site. In general, groundwater flow and contaminant transport occur from the higher elevation of Rattlesnake Mountain and the central plateau toward the Columbia River. Flow of the Columbia River bordering the site is governed by discharge from Priest Rapids Dam. Details on the Hanford Site groundwater setting can also be found in an annual monitoring report (Hartman et al. 1999). The environmental setting is summarized in the background information presented in DOE-RL (1999b).

From its creation in 1943 until recently, Hanford Site facilities were dedicated primarily to the production of weapons-grade plutonium for national defense (Gephart and Lundgren 1995, DOE 1997). The current missions of the Hanford Site are to safely clean up and manage the Hanford Site legacy wastes and to develop and deploy Science and Technology (DOE-RL 1996b). During its nearly 40-year mission to produce special nuclear materials (SNM), the Hanford Site has:

- Fabricated reactor fuel (300 Area)
- Performed research and development (300 Area)
- Operated nine production reactors (100 Areas)
- Operated five chemical separation facilities (200 Areas)
- Fabricated plutonium components for nuclear weapons (200 West Area).

Figure 3-1. Hanford Site Location.



As a byproduct of this work, the Waste Information Data System database currently shows approximately 2,600 waste sites at the Hanford Site. The severity of contamination at these waste sites ranges from contaminated tumbleweeds to radioactive and chemical wastes in tanks at high pH containing high concentrations of organic complexant and salts. The bulk of these wastes were discharged or disposed within the 100, 200, and 300 Areas. However, some wastes were discharged or disposed outside of these operational areas (the Gable Mountain Pond, the waste disposal caissons located adjacent to the Energy Northwest property, the 300 North burial grounds, and the Environmental Restoration Disposal Facility [ERDF] located between 200 West and 200 East Areas, for example). The Hanford Site also includes a commercial low-level waste disposal site operated by US Ecology that is located southwest of the 200 East Area.

For additional information about the Hanford Site environmental setting and past operations at the Hanford Site, readers should refer to the state of knowledge document produced by the GW/VZ Integration Project (DOE-RL 1999b). Further details can be found on the internet http://www.hanford.gov/doe/culres/historic/index.htm. Two links from that site to other internet sites of special interest are the *Historic District Book* and the *More Historic Information*. Other resources are provided in a report on Hanford Site tank cleanup (Gephart and Lundgren 1995) and the DOE's publication on legacy wastes (DOE 1997).

3.2 OVERVIEW OF THE INITIAL ASSESSMENT

As a first step, the SAC (Rev. 0) will be used to perform a single analysis to demonstrate its capability. The Columbia River Comprehensive Impact Assessment (CRCIA), Part II (DOE-RL 1998a), coined the phrase "Hanford Site Disposition Baseline" (HSDB) to describe the suite of disposal and remedial actions that will occur as the Hanford Site moves toward closure. Such a baseline was selected for the initial assessment because it can be related to the current estimated lifecycle cost for Hanford Site cleanup and closure. Alternate remedial actions will not be analyzed as part of the initial assessment and are deferred.

The initial assessment will simulate a combination of 10 radioactive and chemical contaminants. The SAC (Rev. 0) will include simulation of inventory; contaminant release; migration; and fate in the subsurface (i.e., vadose zone and groundwater); contaminant migration and fate in the Columbia River; and risk and impacts to the people, ecology, economy, and cultures of the region. The required analysis for each module is described in Section 3.3.

A major assumption supporting the initial assessment is that the current regional and local climate remains unchanged for the period of analysis. Furthermore, it is assumed that major engineering structures in the region (e.g., Grand Coulee Dam) will be maintained for the long term. Analyses of alternate future climates (e.g., climate change and glacial flooding) and potential future events (e.g., failure or removal of the reservoir system) are deferred.

One of the outcomes of the initial assessment will be an evaluation of how well historical observations are matched. The assessment is being assembled in pieces that are being independently tested and evaluated. A real test of the overall capability will result from the linked simulation of inventory, release, and environmental pathway. Comparisons will be made to field observations of the past 50 years.

3.2.1 A Site Cleanup Scenario – The Hanford Site Disposition Baseline

Part II of the CRCIA (DOE-RL 1998a) states that an assessment "is to be performed maintaining as much consistency as possible with each set of Hanford Site-wide cleanup/disposal decisions and with each subsequent revision. In other words, for the collection of DOE documents which, at any given time, constitutes the approved Hanford Site post-cleanup end state, there will be a corresponding … assessment of resultant impact." Further, Part II notes that "if no officially recognized end-state plan exists for the overall Hanford Site, the … analysts will develop with DOE's recommendations, the most credible surrogate end-state information available." This essentially calls for the HSDB assessment to be consistent with the current definition of the Hanford Site as cleanup proceeds and after all cleanup and waste disposal actions are complete. While Part II of the CRCIA document defined what a HSDB assessment should be, it did not enumerate the specific cleanup and disposal actions. This section of the analysis plan provides the first statement of the HSDB.

The DOE is required in its multiyear plans to provide an estimated lifecycle cost for Hanford Site cleanup and closure. These costs are a function of an assumed baseline end state for the Hanford Site. The end state for the site is the combination of end states for each individual cleanup project, facility, disposal, etc., for the entire Hanford Site. This collection of end-state assumptions represents the HSDB. The multiyear work plans are the primary source of end-state assumptions. However, to ensure consistency across multiple programs, additional insights with regard to the long-term strategy for cleanup and closure of the Hanford Site were drawn from other documents, including the following:

- *Hanford Strategic Plan* (DOE-RL 1996b)
- Environmental Impact Statements (EIS), Environmental Assessments, and Records of Decision
- Site Specification (DOE-RL 1999d)
- *Technical Issues Management List* (FDH 2000)
- Path-to-Closure (DOE 1998, DOE-RL 1998b).

The multiyear work plans and these additional sources provide a set of HSDB assumptions regarding the disposal locations, remedial actions, recovery and treatment efficiencies, etc., that define the end state of the Hanford Site.

The Final Hanford Comprehensive Land Use Plan (HCP) EIS (DOE 1999) and associated Record of Decision (64 FR 61615 1999) were recently issued and presents a preferred alternative for land use for the entire Hanford Site. However, while the HCP EIS has considered the stated values of the public, it focuses on DOE’s role as caretaker for the next 50 years. Accordingly, the land uses identified do not translate into remedial actions or cleanup standards. For example, the EIS indicates the river corridor will not be devoted to residential land use. Rather, the river corridor will be devoted to a combination of recreation and preservation. However, the HCP EIS does not define the remedial actions or cleanup levels consistent with recreation and preservation land use. The EIS indicates the central plateau land use will be industrial and waste management, but does not define the level of cleanup required at individual waste sites to provide an industrial setting (i.e., whether wastes need to be removed from the upper 4.5 m [15 ft]). Consequently, the HSDB does not rely on the HCP EIS to define remedial actions.

3.2.1.1 The 100 Areas. As indicated in the HCP EIS (DOE 1999), as the Hanford Site approaches closure, segments of the Columbia River corridor would be devoted to high- or low-intensity recreation, but the largest portion would be designated preservation to protect cultural and ecological resources. The corridor includes the river islands and a quarter-mile buffer zone.

Wastes within the 100 Areas include spent fuel in K Basins; surplus facilities, including the graphite cores of the production reactors, miscellaneous underground storage tanks, liquid discharge sites, and solid waste burial grounds. In addition, there were discharges directly to the Columbia River from cooling water retention basin, and there are contaminant plumes in the groundwater underlying the 100 Areas because of liquid discharges. In general, the planned remedial actions for the 100 Areas are designed to permit residential occupancy when complete.

The spent fuel will be removed from the 100 Areas and stabilized and packaged for eventual disposal off site in a national repository. Surplus facilities will be removed from the 100 Areas, except the B Reactor that has been declared a national historic monument. Contaminated soils from liquid discharge sites will be removed to a depth of 4.5 m (15 ft) below grade, and all solid wastes will be removed. Except for the graphite cores that will have there own disposal trench, debris from surplus facilities, soils from liquid discharge sites, and solid wastes will be disposed in the ERDF trench on the central plateau. The baseline disposition of specific 100 Area wastes is shown in Table 3-1.

3.2.1.2 The 300/400/600 Areas. In general, the HCP EIS (DOE 1999) indicates that the planned remedial actions for the 300, 400, and 600 Areas should permit continued use of a portion of the site, including the 300 Area, 400 Area, and Energy Northwest (formerly Washington Public Power Supply System) for industry. Segments of the Columbia River corridor would be devoted to high- or low-intensity recreation, but the largest portion would be designated for preservation to protect cultural and ecological resources. Lands west of State Highway 240 to Vernita Bridge, including the Arid Lands Ecology Reserve, the McGee Ranch and Umtanum Ridge, and lands north of the Columbia River, will be designated for preservation. The remainder of the 600 Area would be designed for conservation to support possible multiple uses, including mining of aggregate but excluding grazing.

Wastes within these areas are similar to those in the 100 Areas, except for the spent fuel in K Basins and the graphite cores of the production reactors (i.e., they include some spent fuel and nuclear materials, surplus contaminated facilities, liquid discharge sites, and solid waste burial grounds). Spent fuel within these areas include the light-water reactor, Test Reactor and Isotope Production General Atomics, and the Fast Flux Test Facility fuel interim stored in the 400 Area until storage is available in the 200 Area. Other SNMs include uranium that is interim stored in the 400 Area, 324/327 Building nuclear materials including some tank waste, the 300 Area fuel supply, the inventory of unirradiated uranium, and a few cesium-137 and strontium-90 capsules and isotopic heat sources stored in the 324 Building. All nonessential, surplus buildings and facilities without a post-cleanup use will be removed. All liquid discharge sites and solid waste burial grounds associated with the 300 Area will undergo remedial actions similar to those undertaken in the 100 Areas. Debris from CERCLA remedial actions from these areas will be disposed in the ERDF trench on the central plateau. Wastes from the future decommissioning of Energy Northwest Facilities are not included in SAC (Rev. 0), but it is recognized they and other nearby generators of radioactive waste need to be included in future SAC assessments. The baseline disposition of specific 300, 400, and 600 Area wastes is shown in Table 3-2.

Table 3-1. The Hanford Site Disposition Baseline – 2000 – for the 100 Areas. (3 Pages)

Material Type	Hanford Site Disposition Baseline Assumptions	Data Needed for Simulation of HSDB
Irradiated Fuel • K Basin fuel and associated sludges, debris, water, and equipment	**Spent Fuel** – Final disposition at a national repository.	Inventory, location, and date. (Minimum information needed for the SAC [Rev. 0] is current inventory, location, and date of export from the Hanford Site.)
	K Basin Sludge – Transuranic-contaminated waste to be processed, packaged, and sent to WIPP for final disposal.	Inventory, location, and date. (Minimum information needed for the SAC [Rev. 0] is current inventory, location, and date of export from the Hanford Site.)
	Contaminated Debris (up to 0.9 m [3 ft] below grade) – Excavated and disposed in the ERDF; excavation is backfilled with clean material.	Inventory, volume, location, and date of remedial action (date sent to ERDF, or begin and end dates of continuous and linear remedial action).
	Clean Debris (up to 0.9 m [3 ft] below grade) – Excavated and used as clean backfill; excavation is backfilled with clean material.	Definition of "clean."
	Residual (deeper than 0.9 m [3 ft] below grade) – Fixed contamination is left in place and buried.	• Inventory of residual • Time of remedial action • Location and form of residual - Fixed to concrete - Contaminated soil • Characteristics of cover if one applied.
	Groundwater Plumes –	Addressed under Environmental Contamination - Groundwater.
	Contaminated Water –	• Inventory, volume, location • Fraction of inventory and volume disposed as solid waste after treatment; fraction disposed as liquid. Dates of disposal.
	Contaminated Equipment –	• Inventory, volume • Location of disposal (e.g., ERDF or identify SWBG).
	Waste Deriving from Processing the Fuel and Sludge – Waste generated? Yes or no. If yes, provide the needed information.	• Estimates of waste inventory. • Will it be disposed on site or off site? • If on site, what is the waste form and its release characteristics? • When will it be produced and where will it be disposed?

Table 3-1. The Hanford Site Disposition Baseline – 2000 – for the 100 Areas. (3 Pages)

Material Type	Hanford Site Disposition Baseline Assumptions	Data Needed for Simulation of HSDB
Surplus Facilities (Facility Transition and Facility D&D) • Production Reactors (B, C, D, DR, F, H, KE, KW, and N, including N Basins) • Other surplus facilities and ancillary equipment • B Reactor is National Historical Site and N Reactor will have its own plan	**Production Reactors** – One piece removal of eight production reactors (C, D, DR, F, H, KE, KW, and N, including N Basins) to a disposal site in the northwest corner of the 200 West Area after 75 years.	Inventory (for analysis of disposal in the 200 West Area); date of remedial action; identify SWBG or coordinate location of disposal in the 200 West Area.
	B Reactor – Remain in its present location and developed as a National Historic Site.	Inventory and location are needed for the analysis of long-term risk and impact at its river shore location.
	Other Surplus Facilities and Ancillary Equipment: **Contaminated Debris (radioactive or mixed waste up to 0.9 m [3 ft] below grade)** – Excavated and disposed in the ERDF; excavation is backfilled with clean material.	Inventory, location (e.g., facility), date of the remedial action. If completed over an extended period of time, provide start date and end date.
	Purely Hazardous Waste (nonradioactive) – Packaged, shipped, and disposed off site.	Inventory, location, and date of the remedial action (i.e., date of shipment off site).
Surplus Facilities (Facility Transition and Facility D&D)	**Clean Debris (up to 0.9 m [3 ft] below grade) –** Excavated and used as clean backfill; excavation is backfilled with clean material. Note: Debris includes surplus facilities, ancillary equipment, and ancillary piping.	Definition of "clean."
Environmental Contamination - Groundwater • 100 Area Plumes (riverbank springs, seepages, Columbia River, and groundwater)	**Contaminated Groundwater and Vadose Zone and Aquifer Sediments in Contact with Groundwater** – Simulate as a no-action case.	Spatial distribution in three dimensions of the concentration of potential contaminants of concern (e.g., concentration, spatial location, porosity, and date). Initial condition or history match information for simulation of contaminant migration and fate. (Minimum information needed for the SAC [Rev. 0] is estimate of plume mass today for history match; other releases and the physics of migration will determine the mass in the groundwater today.)

Table 3-1. The Hanford Site Disposition Baseline – 2000 – for the 100 Areas. (3 Pages)

Material Type	Hanford Site Disposition Baseline Assumptions	Data Needed for Simulation of HSDB
Environmental Contamination - Soil Sites • Liquid Disposal Sites - Cribs (H-3; Sr-90; Cs-137; C-14, nitrates, and sulfates) • Liquid Disposal Sites (cribs, ponds, ditches, and other)	**100 Area Soil Sites** – Clean up to residential standards per the RODs. Excavate to 4.5 m (15 ft) below the structure. (Note: Structures range from grade to 4.5 m [15 ft] below grade; therefore, some excavations approach the groundwater level.)	Inventory, location, and date of the remedial action. If completed during an extended period of time, provide start and end dates • Inventory excavated and disposed in ERDF • Estimate of any transuranic-contaminated material inventory that would be packaged and exported to WIPP • Residual inventory not remediated and its composition and distribution in the subsurface.
MUSTs	**100 Area MUSTs** – Clean up to residential standards per the RODs. This means to excavate or pull, crush, and dispose in the ERDF.	Same as for above "Environmental Contamination – Soil Sites."
Solid Waste • Pre-1970 unsegregated buried transuranic-contaminated waste; suspect transuranic-contaminated buried waste and inactive waste sites	**100 Area Solid Waste Burial Grounds** – Clean up to residential standards per the RODs; excavate the solid waste and dispose in the ERDF.	Inventory, location, and date of the remedial action. If completed over an extended period of time, provide start and end dates. • Inventory excavated and disposed in ERDF • Estimate of any transuranic-contaminated material inventory that would be packaged and exported to WIPP • Residual inventory not remediated and its composition and distribution in the subsurface.
• Newly Generated Solid Waste (Onsite generated within the 100 Areas)	**Newly Generated Solid Waste** – All LLW and treated mixed LLW disposed in 200 Area solid waste burial grounds.	Inventory estimate of waste to be generated; location of disposal (i.e., operational area (200 East or 200 West, and trench or aggregated release area) see Solid Waste Information Forecast Tracking for dates volumes, and inventory of waste generation and disposal.

D&D = decontamination and decommissioning
LLW = low-level waste
MUST = miscellaneous underground storage tank
ROD = Record of Decision
SWBG = solid waste burial ground
WIPP = Waste Isolation Pilot Plant

Table 3-2. The Hanford Site Disposition Baseline – 2000 – for the 300, 400, and 600 Areas. (3 Pages)

Material Type	Hanford Site Disposition Baseline Assumptions	Data Needed for Simulation of HSDB
Irradiated Fuel Example for 300/400 Areas: • FFTF Fuel • Na-bonded EBR-II Fuel • TRIGA (308 Building) • LWR (generally high to moderately irradiated fuel)	**Spent Fuel** – All weapons production and nonweapons production spent fuel will be exported from the Hanford Site for final disposal. **Additional Processing** – No further processing of SNF is necessary after interim storage and prior to disposal.	Inventory, location (current location and future onsite location), and date of movement; especially date of export from the Hanford Site • FFTF Fuel • Na-bonded EBR-II Fuel • TRIGA Fuel • LWR Fuel. (Minimum information needed for the SAC [Rev. 0] is current inventory, location, and date of export from the Hanford Site.)
SNM Inventory • Nonself protecting SNM and NM and unirradiated uranium • Green FFTF fuel	**2500 Low Enriched Uranium Billets** (i.e., 1.6 million lb of normal and low enriched uranium) - Transitioned to be of beneficial use in United Kingdom. **Unirradiated FFTF Fuel** – Transferred from the 308 Building to PFP in the 200 West Area for secure interim storage before export from the Hanford Site.	Inventory, location (current location and future onsite location), and date of movement, especially date of export from Hanford. (Minimum information needed for SAC [Rev. 0] is current inventory, location, and date of export from the Hanford Site.)
Sr-90/Cs-137 Capsules • Small number of Sr-90/ Cs-137 Capsules • Isotopic heat sources stored in the 324 Building, as returned from FRG	**Sr-90/Cs-137 Capsules** – Transferred to the 200 Area Central Plateau for interim storage before final disposition decision and disposal off site.	Inventory, location (current location and future onsite location), and date of movement, especially date of export from the Hanford Site. (Minimum information needed for the SAC [Rev. 0] is current inventory, location, and date of export from the Hanford Site.)
Surplus Facilities (Facility Transition and Facility D&D) • Reactor (FFTF) • FMEF • 324/325/327 Buildings • Other Existing 309, 306, 308, etc., Facilities	**Surplus Facilities and Ancillary Equipment** **Contaminated Debris (radioactive or mixed waste up to 0.9 m [3 ft] below grade)** – Excavated and disposed in the ERDF; excavation is backfilled with clean material.	Inventory, location (e.g., facility), date of the remedial action. If completed during an extended period of time, provide start date and end date. Indicate whether a surface cover would be constructed. If so, when would the surface cover be built and what is its expected performance (i.e., infiltration rate).

Table 3-2. The Hanford Site Disposition Baseline – 2000 – for the 300, 400, and 600 Areas. (3 Pages)

Material Type	Hanford Site Disposition Baseline Assumptions	Data Needed for Simulation of HSDB
Surplus Facilities • MUSTs (associated with facilities)	**Purely Hazardous Waste (nonradioactive) –** Packaged, shipped, and disposed off site.	Inventory, location, and date of the remedial action, especially the date of shipment off site.
• Advanced Reactors Facilities are the PRTR/309 Building; Nuclear Energy Legacy facilities (nonnuclear used in LMFBR program [e.g., PAL, HTSF, etc.] and the FFTF/FMEF)	**Clean Debris (up to 0.9 m [3 ft] below grade) –** Excavated and used as clean backfill; excavation is backfilled with clean material. (Note: Debris includes surplus facilities, ancillary equipment, and ancillary piping.)	Definition of "clean."
Energy Northwest WNP-2	Will reflect Energy Northwest closure plan.	Inventory, location, date.
Environmental Contamination - Groundwater • 300 Area Plumes • 600 Area Plumes	**Contaminated Groundwater, and Vadose Zone and Aquifer Sediments in Contact with Groundwater –** Simulate as a no-action case.	Spatial distribution in three dimensions of the concentration of potential contaminants of concern (PCOC), (e.g., concentration, spatial location, porosity, and date). Initial condition for simulation of future migration and fate. (Minimum information needed for SAC [Rev. 0] is estimate of plume mass today for history match; other releases and the physics of migration will determine the mass in the groundwater today.)
Environmental Contamination - Soil Sites • Liquid Disposal Sites - cribs, ponds, and ditches • Liquid Disposal Sites - MUSTs	**300 Area Soil Sites –** Clean up to industrial standards per RODs; excavate to 4.5 m (15 ft) below the structure. (Note: Structures range from grade to 4.5 m [15 ft] below grade; therefore, some excavations approach the groundwater level.)	Inventory, location, and date of the remedial action. If completed during an extended period of time provide start date and end date. • Inventory excavated and disposed in ERDF. • Estimate of any TRU-contaminated material inventory that would require packaging and shipment to WIPP. • Residual inventory not remediated, its composition, and distribution in the subsurface.
Solid Waste • Pre-1970 unsegregated buried TRU-contaminated waste, suspect TRU-contaminated buried waste, and inactive waste sites	**300 Area Solid Waste Burial Grounds –** Clean up to industrial standards per RODs; excavate the solid waste and dispose in the ERDF.	Inventory, location, and date of the remedial action. If completed over an extended period of time provide start date and end date. Assume all remedial action wastes are disposed in ERDF. (Applies all solid waste burial grounds.)

Table 3-2. The Hanford Site Disposition Baseline – 2000 – for the 300, 400, and 600 Areas. (3 Pages)

Material Type	Hanford Site Disposition Baseline Assumptions	Data Needed for Simulation of HSDB
Solid Waste • Retrievably Stored Solid Waste – TRU Alpha (e.g., Caissons 618-11 Burial Ground).	**618-10 and 618-11 Suspected TRU-Contaminated Waste** – Stabilized, packaged, interim stored in the 200 Area Central Plateau, and then disposed off site.	Inventory, location, and date of remedial action for 618 caissons. The inventory will include the fraction of waste from caissons disposed in LLW, fraction packaged and disposed off site as TRU at WIPP, and fraction remaining as residual contamination.
• Retrievably stored liquid wastes mixed, TOSCA (Hexone, etc.)	**Hexone** removed and disposed off site under 300-FF-2 (DOE-RL 1997). Other TOSCA wastes addressed by RODs and also disposed off site.	Original inventory, location, and date. Present day residual inventory, if any, location, and date. Actual or proposed date of offsite disposal.
• Radioactive Sodium at FFTF and Legacy Wastes	**Radioactive Sodium and Legacy Wastes** – Transferred off site or beneficially used on site.	Inventory, location, and date of transfer off site or use on site.
• Newly Generated Solid Waste (Nonradioactive, Demolition Waste)	**Inert Demolition Waste** – Disposed in South 600 Area Pit 9.	Inventory, location, and date (only if it includes nonhazardous chemical of interest).
• Newly Generated Radioactive Solid Waste (TRU and Non-TRU)	**Newly Generated Non-TRU Radioactive Waste** – LLW and treated mixed LLW disposed in the 200 Area Central Plateau solid waste burial grounds.	Inventory, location (e.g., trench number), and date of disposal in the 200 Area solid waste burial grounds.
	Newly Generated TRU Radioactive Waste – Processed, packaged, and interim stored at the 200 Area Central Plateau pending transport to WIPP for final disposal.	Inventory, source location at the Hanford Site, and date of export to the WIPP.

D&D = decontamination and decommissioning
FFTF = Fast Flux Test Facility
FMEF = Fuel Materials Examination Facility
FRG = Federal Republic of Germany
HTSF = High Temperature Sodium Facility
LLW = low-level waste
LMFBR = Liquid-Metal Fast Breeder Reactor
LWR = light water reactor
NM = nuclear material
PAL = processing and analytical laboratories
PCOC = potential contaminants of concern
PFP = Plutonium Finishing Plant
PRTR = Plutonium Recycle Test Reactor
ROD = Record of Decision
SNF = spent nuclear fuel
SNM = special nuclear material
TOSCA = *Toxic Substances Control Act*
TRIGA = Test Reactor and Isotope Production General Atomics
TRU = transuranic
WIPP = Waste Isolation Pilot Plant

3.2.1.3 Central Plateau. Wastes within the central plateau include spent fuel; other SNMs, including Plutonium Finishing Plant (PFP) material and cesium-137 and strontium-90 capsules; surplus facilities, including canyons and tunnels, single- and double-shell tank wastes, liquid discharge sites, unplanned release sites, and solid waste burial grounds. The central plateau, a rectangular parcel, includes the 200 West and 200 East Areas, the commercial low-level waste disposal facility operated by US Ecology, the ERDF trench, and the B/C cribs that are located south of the 200 East Area and east of the US Ecology site. Virtually all of the radioactive and chemical wastes generated during Hanford Site operations that will remain on site will be disposed within the central plateau. The HCP EIS (DOE 1999) indicates that future land use will be limited to a combination of industry and waste management activities.

Spent fuel, SNMs, immobilized high-level waste, and transuranic waste will be transported off site before site closure. Tank wastes will be retrieved, separated into high-level and low-activity fractions, and solidified. The low-activity fraction will be disposed on site, and the high-level fraction will be disposed off site. Low-level radioactive wastes from these activities will also be disposed as solid waste on site. Remedial actions for past tank leaks, future tank losses, and tank waste residuals will be limited to in-place stabilization and the placement of surface barriers. It is assumed that similar remedial actions will be taken for all liquid discharge sites, unplanned release sites, and solid waste burial grounds within the central plateau. All nonessential, surplus buildings and facilities without a post-cleanup use will undergo decontamination and decommissioning. These will include all canyon buildings and the PFP. Debris from those that can be removed will be disposed in the ERDF trench. The ERDF trench, and the trench that receives the graphite cores of the production reactors, will receive a protective surface barrier when closed. Other facilities, including the canyon buildings and plutonium-uranium extraction building tunnels, will be in-place stabilized and covered with a protective surface barrier. For the purposes of the SAC (Rev. 0) analysis, it is assumed that groundwater contaminant plumes beneath the Hanford Site will not require remedial action. This assumption is made for the initial assessment to avoid the introduction of complex and dynamic decision logic that would initiate and terminate pump-and-treat actions. The baseline disposition of specific central plateau wastes is shown in Table 3-3.

3.2.2 Contaminants to be Modeled

As noted in Section 2.0, current plans call for the inclusion of multiple radionuclides representing a range of mobilities and general hazardous chemicals. In response, the SAC (Rev. 0) will be able to process up to 10 contaminants. Most contaminants will be analyzed as either a radionuclide or a chemical, but some such as uranium may be analyzed in both forms. To be clear, each isotope of uranium would be a separate radionuclide analysis. Thus, analysis of a single isotope of uranium and analysis of uranium as a chemical would count as the analysis of two contaminants in a list of 10.

Radionuclides for which data will be gathered to support simulation include tritium, technetium-99, iodine-129, uranium, strontium-90, cesium-137, and plutonium-239/240. Information on uranium isotopes (e.g., uranium-232, -233, -234, -235, -236, or -238) will be gathered to better understand its state in waste or the environment (i.e., natural, depleted, and enriched uranium). Uranium will be modeled as uranium-238 in the initial assessment.

Table 3-3. The Hanford Site Disposition Baseline – 2000 – for the Central Plateau. (5 Pages)

Material Type	Hanford Site Disposition Baseline Assumptions	Data Needed for Simulation of HSDB
Irradiated Fuel • Example is K Basin Fuel stabilized in an MCO in the CSB Facility, SNF stored in Burial Ground, SNF in T Plant, etc. • Covers Shippingport fuel, TRIGA fuel, including that in LLBG, FFTF fuels, and miscellaneous fuel materials	**Spent Fuel** – All weapons production and nonweapons production spent fuel will have final disposition at a national repository. **Additional Processing** – No further processing of SNF is necessary after interim storage and before disposal.	Inventory (for mass balance): • K Basin fuel • TRIGA, LWR, and FFTF fuels – in the 400 Area and interim stored in the 200 Area ISA. • Shippingport fuels in T Plant removed to 200 Area ISA. • Na-Bonded FFTF SNF transferred off site to INEEL for disposition. (Minimum information needed for the SAC [Rev. 0] is current inventory, location, and date of export from the Hanford Site.)
SNM and NM Inventory • PFP - materials - solutions, metal, polycubes • PFP - existing oxides • PFP - holdup material • Unself-protecting NM materials (e.g., fuel grade PuO_2, green FFTF fuel elements, etc., and other [Weapons Usable Fissile Material]) • Unirradiated uranium	**Special Nuclear Material and Nuclear Material** – All SNM and NM inventory will be removed from the Hanford Site and stored in a location to be determined.	Inventory (for mass balance): • PFP - materials (e.g., solutions, metal, polycubes) • PFP - existing oxides • PFP - holdup materials • Unself-protecting NM materials (e.g., fuel grade PuO2, green FFTF fuel elements, etc., and other [Weapons Usable Fissile Material]) • Unirradiated uranium (Minimum information needed for the SAC [Rev. 0] is current inventory, location, and date of export from the Hanford Site.)
Sr-90/Cs-137 Capsules • Storage in WESF	**Cesium and Strontium Capsules** – Cesium and strontium capsules declared to be waste will be transported to a National Repository for final disposal.	Inventory (for mass balance) (Minimum information needed for the SAC [Rev. 0] is current inventory, location, and date of export from the Hanford Site.)
DST/SST Systems • DST Waste • SST Waste • ILAW - a tank waste stream • IHLW - a tank waste stream	**SST Retrieval** – The system will be capable of meeting the TPA 99% waste volume removal milestone.	• Inventory of the 99% waste volume removed from the SSTs and DSTs. • Sequence and dates of SST, DST, MUST tank waste retrieval.
	DST and MUSTs Retrieval – The system will be capable of meeting the TPA 99% waste volume removal milestone.	Inventory of the 99% removed.

Table 3-3. The Hanford Site Disposition Baseline – 2000 – for the Central Plateau. (5 Pages)

Material Type	Hanford Site Disposition Baseline Assumptions	Data Needed for Simulation of HSDB
DST/SST Systems	**High-Level Fraction** – Will be interim stored until shipped off site to a national repository.	Inventory split to HLW stream (for mass balance).
	Low-Activity Fraction – Will be immobilized and disposed on site in a 200 Area disposal ground designed for the ILAW.	Inventory split and release models for ILAW stream disposed in a new disposal facility; dates and rates of ILAW disposal.
	Retrieval, Separation, and Vitrification Operation Waste Streams – Will be disposed in solid waste burial grounds managed by ORP-RPP in the 200 East Area.	Disposal location, inventory estimates, and release models for wastes generated during the retrieval, separation, and vitrification operations (e.g., wastes ranging from contaminated clothing and tools to failed equipment such as pumps and melters); dates of waste generation and disposal.
• SSTs, DSTs, MUSTs, Ancillary Storage Tanks	**Tank Closure –** All SST, DST, MUSTs, and Ancillary Storage Tanks will be stabilized to prevent subsidence and closed in place.	• Inventory of the 1% volume residual • Inventory associated with in-tank equipment and structures.
• SST/DST Subsurface Soils	All in-tank equipment, structures, and underlying and adjacent contaminated soils will be disposed in place.	Inventory, waste form, release models, and release model data for the residual in the stabilized tank, in-tank equipment, and structures.
	Surface Barrier – All tanks will have a surface barrier consistent with their contents.	• Geochemical mobility of contaminants in subsurface soils and sediments • Infiltration rate through the surface and periods of time representing pre-Hanford, the Hanford Site operational period, after barrier construction, after barrier degradation.

Table 3-3. The Hanford Site Disposition Baseline – 2000 – for the Central Plateau. (5 Pages)

Material Type	Hanford Site Disposition Baseline Assumptions	Data Needed for Simulation of HSDB
Surplus Facilities (Facility Transition and D&D) • Existing Canyon Buildings – (PUREX, B Plant, T Plant, U Plant and REDOX) • Other Existing Facilities • New Facilities (e.g., CVDF, CSB, WRAP, etc.) • ERDF • PUREX Tunnels • MUSTs	**Canyon Buildings** – PUREX, B Plant, T Plant, U Plant, and REDOX will be brought down to their cover block grade, stabilized, and covered with a surface protective barrier (i.e., entombed in place).	Inventory in the debris removed from the surplus facilities and disposed in ERDF, and its waste form (e.g., contaminated concrete, contaminated metal); dates of remedial actions. Inventory in the canyon buildings at and below the cover blocks, and the waste forms, release models, and release model parameters.
	PUREX Tunnels – Will be stabilized to prevent subsidence and covered with a protective surface barrier.	Inventory, waste form, release models, and release model parameters for in-place disposal of PUREX tunnels; dates of remedial action.
	PFP Production Area – Will be decontaminated, stabilized to prevent subsidence, and covered with a surface barrier.	Inventory, waste form, release models, and release model parameters for PFP D&D; dates of remedial action.
	MUSTs – If they ever contained HLW, they will be treated the same as SSTs.	(See notes above on SST/DST waste removal and remedial action.)
	MUSTs – If they never contained HLW, they will be stabilized the prevent subsidence and covered with a protective surface barrier.	Inventory (chemical and/or LLW), waste form, release models, and release model parameters; dates of remedial action. Performance of the protective surface barrier to be specified.
	New Facilities, Other Existing Facilities – Those without an identified post-closure mission will be decontaminated and decommissioned with debris going to the ERDF.	Inventory, waste form, release models, and release model parameters for ERDF disposal; dates of D&D actions. The time of construction and performance of protective surface barriers, and their degradation processes and degraded performance.
	ERDF – This recipient of all CERCLA wastes generated during cleanup by the ERC will be closed with a protective surface cover.	Inventory, release models, and release model parameters for the wastes disposed in each cell; date of placement and performance estimates for the protective surface barrier; long-term performance estimates of the installed double liner.

Table 3-3. The Hanford Site Disposition Baseline – 2000 – for the Central Plateau. (5 Pages)

Material Type	Hanford Site Disposition Baseline Assumptions	Data Needed for Simulation of HSDB
Environmental Contamination - Groundwater • 200 Area Plumes	**Groundwater** – A no-action assumption is made for all groundwater contamination, except carbon tetrachloride.	Spatial distribution (areal extent and depth) and concentration of potential contaminants of concern. (Initial condition for simulation of future migration and fate.)
	Groundwater – Carbon tetrachloride being remediated as pump and treat – assume CCl_4 level is at the cleanup standard.	Inventory of carbon tetrachloride removal; dates of remedial action. (Minimum information needed for the SAC [Rev. 0] is estimate of plume mass today for history match; other releases and the physics of migration will determine the mass in the groundwater today.)
Environmental Contamination - Soil Sites • ~700 waste sites: Liquid Disposal Sites - cribs, ponds, ditches, and other, including unplanned releases and SALDS • MUSTs (not SST or DST related)	**Soil Sites Outside the Central Core** – Clean up to standards. Excavate to 4.5 m (15 ft) below the structure (note structures range from grade to 4.5 m [15 ft] below grade).	Inventory excavated and disposed in the ERDF; dates of remedial actions. Inventory of residual and its form following cleanup of past practice liquid discharge sites. Estimate of any TRU contaminated materials that would be packaged and exported to WIPP.
	Soil Sites Inside the Central Core – Stabilized and covered with a protective barrier.	Inventory and waste form to support release modeling; dates of barrier construction and performance (e.g., high integrity period and degraded period).
	MUSTs – Stabilized in place and covered with a protective barrier.	Inventory and waste form to support release modeling.
Solid Waste • Pre-1970 unsegregated TRU-contaminated buried waste, suspect TRU-contaminated buried waste, and inactive waste sites	**Pre-1970 TRU-Contaminated Buried Waste** – Stabilized and covered with a protective barrier.	Inventory and waste form to support release modeling; dates of barrier construction and barrier performance.
• Retrievably Stored TRU Solid Waste (including Z-9 Trench soil)	**Retrievably Stored TRU Solid Waste** – Retrieved and transported to WIPP for final disposal.	Inventory (for mass balance) and date of offsite disposal.
• Alpha Caissons 200 West TRU Storage and the one Near 222-S Lab	Alpha caissons 200 West Area retrieved and transported to WIPP for final disposal.	Inventory (for mass balance) and date of offsite disposal.
• Post-1970 Segregated Non-TRU Buried Waste	**Post-1970 Segregated Non-TRU Buried Waste** – Stabilized and disposed in place with a protective surface barrier.	Inventory and waste form for release modeling; date of barrier construction and barrier performance.

Table 3-3. The Hanford Site Disposition Baseline – 2000 – for the Central Plateau. (5 Pages)

Material Type	Hanford Site Disposition Baseline Assumptions	Data Needed for Simulation of HSDB
Solid Waste • Retrievably Stored Solid Waste Non-TRU	**Retrievably Stored Non-TRU Solid Waste** – Stabilized in place and disposed in present LLW burial ground location with protective surface barriers.	Inventory and waste form for release modeling; date of barrier construction and barrier performance.
• Grout Site - Post-1970 LLW	**Grout Site – Post-1970 LLW Solid Waste** – Disposed in place without a protective barrier.	Inventory of the grout waste form, and release model parameters for the grout waste form release model of the phosphate/sulfate wastes.
• Newly Generated Solid Waste – Onsite Generated and Offsite Receipts Non-ERDF	**Newly Generated Solid Waste** – LLW and treated mixed LLW disposed in the 200 Area Central Plateau solid waste burial grounds.	Inventory, location, and waste form for release modeling; date of barrier construction and barrier performance.
• Newly Generated Solid Waste – Onsite Generated Receipts from ER program – ERDF	**ERDF** – Disposal in place with a protective surface barrier.	Inventory of the ERDF, waste form, release models, and release model parameters; dates of barrier construction over cells.
• Active Waste Disposal Sites - LLW Burial Grounds (including Submarine Reactor Compartments)	**Active LLW Burial Grounds** – LLW and treated mixed LLW disposal in place after stabilized to prevent subsidence, a protective surface barrier constructed.	Inventory of the SWBGs, waste form, release models, and release model parameters, (e.g., high integrity containers, naval reactor compartments, other debris); date of barrier construction.
• Active Waste Disposal Sites - US Ecology Commercial LLW Burial Site	**Commercial LLW Disposal Facility** – Stabilized and covered with a protective surface barrier as in closure plan (as amended and accepted by the Washington State Department of Health).	Inventory of the commercial LLW site, waste form and release models, and protective barrier performance; dates of barrier construction and trench closure.

CSB	= Canister Storage Building	LLBG	= low-level radioactive waste burial ground	SALDS	= State-Approved Land Disposal Site
CVDF	= Cold Vacuum Drying Facility	LLW	= low-level waste	SNF	= spent nuclear fuel
D&D	= decontamination and decommissioning	LWR	= light water reactor	SNM	= special nuclear material
DST	= double-shell tank	MCO	= multicanister overpack	SST	= single-shell tank
ER	= Environmental Restoration	MUST	= miscellaneous underground storage tank	SWBG	= solid waste burial ground
ERC	= Environmental Restoration Contractor	NM	= nuclear material	TPA	= Tri-Party Agreement
FFTF	= Fast Flux Test Facility	ORP	= Office of River Protection	TRIGA	= Test Reactor and Isotope Production General Atomics
HLW	= high-level waste	PFP	= Plutonium Finishing Plant	TRU	= transuranic
ILAW	= immobilized low-activity waste	PUREX	= Plutonium-Uranium Extraction (Plant)	WESF	= Waste Encapsulation and Storage Facility
INEEL	= Idaho National Environmental Engineering Laboratory	REDOX	= Reduction-Oxidation (Plant)	WIPP	= Waste Isolation Pilot Plant
ISA	= interim storage area	RPP	= River Protection Project	WRAP	= Waste Repackaging Acceptance Plant

Chemicals for which data will be gathered to support simulation include the organic compound carbon tetrachloride and the inorganic metal chromium. Carbon tetrachloride will be modeled as a molecule experiencing abiotic degradation through a half-life mechanism and sorption. Chromium will be modeled as hexavalent chromium. Uranium may be simulated as a chemical to estimate its health impact on the human kidney.

3.2.3 Global Assumptions

Assessments rely on two levels of problem definition. One level is the definition necessary to estimate the inventory distribution in space and time, the contaminant distribution in the environment, and the risk and impacts to society and the ecology. Section 3.3 will define the level-one setting. The second level is the definition of large-scale and long-term conditions, including the climate and environmental setting. These conditions are global assumptions regarding the physical setting of the assessment.

3.2.3.1 Climate and Reservoir Operation. The second level of definition for the initial assessment is a baseline scenario that assumes the future (i.e., at least for the next 1,000 years), is inconsequentially different from today, and basically constitutes present-day conditions. It is assumed the current regional and local climate will remain unchanged for the 1,000-year period of this analysis. It is also assumed that major engineered structures in the region (e.g., the reservoir system on the Columbia River) will be maintained. The recorded climate and environmental response (e.g., Columbia River stage and discharge records) since startup of site operations will be used to simulate the period from 1944 to present. The climate record of the last 30 years (e.g., 1961 to 1990) will be used to represent the future climate. Consequently, the Hanford Site will remain a semi-arid shrub-steppe environment. The riparian zone, Columbia River, and the river's ecosystem will remain essentially unchanged for 1,000 years. Also, human populations, economic conditions, and cultures will be unchanged and based on the current socio-economic setting. It is assumed that preservation and conservation will dominate land use and result in a Hanford Site landscape virtually unchanged from today.

These assumptions are central to level one analysis definition because the climate, vegetation, and surface soils act to define the infiltration rate and, hence, the leaching of waste and recharge to the unconfined aquifer. Similarly, the flow in the Hanford Reach of the Columbia River is defined completely by the water management practices of the reservoir system. The occurrence of low flows associated with drought, and flood events associated with rapid snow-melt, are moderated by the reservoir system and especially the operation of Grand Coulee Dam. Other reservoirs below Grand Coulee (but upstream of the Hanford Site) do not have sufficient storage and simply route the Grand Coulee discharge downstream as they generate power.

3.2.3.2 Alternate Future Scenarios. Analyses of alternate future climates and potential future events are deferred. Candidate future climates that may be studied include a rapid climate change associated with global warming and the longer-term onset of the next ice age with its associated catastrophic glacial flooding. Issues regarding a sitewide application of irrigated agriculture, river channel change, the construction or removal or dredging of current or future dams are all deferred to future analyses. Scenarios depicting potential changes to receptors, including demographic changes within the Columbia River corridor (especially downstream of the Hanford Site) and institutional or cultural changes, are also deferred. Application of a residential (farmer) agricultural exposure scenario, which is described in later sections, does not involve widespread irrigated agriculture. Rather, the scenario involves relatively few isolated family farms that use water from the unconfined aquifer.

3.2.3.3 Background and Non-Hanford Contributions. The analysis of background and non-Hanford contributions to contamination and risk will consider only the Columbia River. These contributions to the analysis will be introduced in the quality of water entering the analysis from Priest Rapids Dam, and the Yakima, Snake, and Walla Walla Rivers. Simulations will be run with only the background and non-Hanford contributions and a second time with Hanford Site contributions superimposed on the background and non-Hanford contributions. Background contributions from the Hanford Site (e.g., in the soil or groundwater) are neglected in the SAC (Rev. 0) because of the relatively small contribution the Hanford Site background makes to the Columbia River (considering the upstream drainage). The Hanford Site groundwater contribution is approximately 1.1 cms (40 cfs) compared to the Columbia River flow in the Hanford Reach of 3,400 cms (120,000 cfs). By simulating background and Hanford Site contributions plus background, analysts will be able to evaluate and present the statistical difference between the two results.

3.3 PLANNED ANALYSIS

This section describes the overall planned analysis for the SAC (Rev. 0) and defines the case to be analyzed for each module of the SAC. This description informs those interested in the character of the first analysis, and guides those planning efforts necessary to gather data and conduct simulations. The description does not include the distributions of data to be applied in the assessment. Those data will become available once the data gathering activity is completed next fiscal year.

Section 3.3.1 describes the temporal and spatial resolution of the overall analysis. Any specific remarks regarding the spatial and temporal resolution of a module will be included under its problem statement. The planned analysis for each module (i.e., inventory, release, vadose zone, groundwater, Columbia River shore, Columbia River, and risk and impact) is presented in terms of a problem statement, endpoints for analysis, uncertainty estimation, and output. Those analyses are described in Sections 3.3.2 through 3.3.8.

3.3.1 Temporal and Spatial Resolution of the Assessment

The time period of the assessment shall be from 1944 through 3050 inclusive, and includes 1,000 years following the assumed Hanford Site closure date of 2050. A 1,000-year period of analysis is consistent with the 1,000-year period of regulatory compliance noted in DOE Order 435.1 for low-level radioactive wastes. This period of analysis is also adopted to not overly tax resources during the initial demonstration of an assessment capability. Resolution of releases to the environment during the operational period from 1944 to present (i.e., 2000) will be, at most, annual and at least five-year intervals to ensure temporal realism and to support history matching efforts based on times of first detection and monitored mass in the groundwater aquifer. During the period from present day until site closure, the temporal resolution of releases will be the same (i.e., at most annual and at least five-year intervals) to ensure a realistic representation of disposals and facility decontamination and decommissioning. Thereafter, the temporal resolution will be sufficient to support the risk and impact assessment. The groundwater and river environments will be simulated at annual resolution. Considering seasonal variations on the ecology, annual average values from a groundwater or river simulation will be supplemented with empirical data that estimate seasonal variations in water quality.

The assessment will simulate up to eight aggregated release areas where vadose zone releases will be introduced to the water table of the unconfined aquifer. To demonstrate releases from typical waste disposal areas, aggregate release areas will consist of one 100 Area, the 300 Area, and six distinct regions of the central plateau. Individual waste sites (e.g., liquid discharge sites, solid waste burial grounds, facilities) within each of the aggregated release areas will be simulated using representative release models and vadose zone soil/sediment columns. Releases to the water table will be aggregated and introduced into the aquifer over a representative area of the water table.

Up to 200 points in the environment (i.e., x and y coordinates) will be identified to accumulate contaminant concentration data from each simulation for subsequent human health risk and economic impact analysis. The temporal files for individual points of interest shall store up to 200 output time steps at each of the 200 points.

The assessment will store information up to 2,500 locations from throughout the groundwater assessment domain for up to 50 time planes to support geographic representations of the areal distribution of contaminants. Information from up to 2,000 locations from the Columbia River assessment domain for up to 200 time planes will be saved to support the ecological assessment. Socio-cultural assessment relies on the areal distribution of groundwater, river water, and river sediment contamination to assess impact. Such impacts are best observed by generating areal maps of contaminant distribution.

3.3.2 Inventory

Problem Statement

A. Inventory for specific waste disposal and storage locations for the period from 1944 to present (i.e., December 1999) will be based on disposal records, process knowledge, and tank and field sample results. The inventory for the initial assessment will merge data from records with results from the Hanford Defined Waste model (Agnew et al. 1997) and estimates of tank leaks being developed by the River Protection Project during fiscal year 2000.

B. Where available, the inventory of waste disposal and its uncertainty for the period 1944 to present will be developed in as much detail as is available (i.e., the inventory for specific liquid discharge sites, solid waste sites, and facilities will be catalogued individually if records exist).

C. Where inventory data are absent, similar waste forms or releases may be aggregated to produce an estimated inventory of waste disposal and its uncertainty for the period 1944 to present. Inventory uncertainty is inherently higher for individual waste sites and less for groups of similar releases.

D. Inventory for specific waste disposal and storage locations from present day (i.e., January 2000) to site closure (i.e., assume December 2050) will be based on the assumptions for waste retrieval and treatment, waste remedial action, waste disposal, etc., captured in the HSDB (Section 3.2.1) and waste disposal forecasts. Where possible, the assumptions will be applied to entire classes of waste or waste forms (e.g., all liquid discharge sites in the 100 and 300 Areas will be excavated to 4.5 m [15 ft] below grade with all soils transported to and disposed in the ERDF trench).

E. The total and site-specific radionuclide inventory and its uncertainty will be developed for the following radionuclides: tritium, technetium-99, iodine-129, uranium-238, strontium-90, cesium-137, and plutonium-239/240. Estimates of other uranium isotopes will be available through isotopic ratio estimates in the SAC (Rev. 0).

F. The total and site-specific chemical inventory and its uncertainty will also be developed for the organic carbon tetrachloride, the inorganic metal chromium (i.e., hexavalent chromium), and uranium.

G. Perturbations to HSDB assumptions for waste retrieval and treatment will not be examined in the initial assessment.

H. Individual total inventory estimates (from items E – F) will be scaled to fit within the distribution of total inventory. Each realization of total inventory will be used to scale a realization of the individual inventories (from items A – D). This will ensure that uncertainties in individual inventories do not combine to create unrealistic total inventories.

Endpoints for Analysis

I. The Inventory Module will provide estimates of the volume and mass of contaminant as a function of time. The estimates will address inventory delivered to each release model (i.e., (1) delivered directly to environment, e.g., discharges to cribs, ponds, trenches, reverse wells, (2) disposed in specific waste forms, e.g., in solid waste burial grounds, immobilized low-activity waste (ILAW), (3) retained in facilities, (4) discharged to the Columbia River, and (5) emitted to the atmosphere). If possible, the time interval will be annual. If the release estimate relies on process knowledge and simulations of waste discharges, the time interval may be a function of Hanford Defined Waste simulations and, therefore, be constrained to a five-year interval. These estimates will reflect the history and forecast of disposals from 1944 through site closure (i.e., assumed in 2050).

J. The disposals are assumed complete at the time of site closure, and the inventory in the environment unchanged, except by release to the environment and migration within the environment.

K. Remedial actions at specific sites are assumed to occur, at most, once.

Uncertainty Estimation

L. An expert elicitation will be used to obtain estimates of the character of the recorded data (i.e., best estimate, conservative, bounding) and to obtain initial estimates of the range around the recorded or estimated inventory value. Onsite experts in Hanford Site inventories and their estimation will be assembled. An expert elicitation involves creating a panel of expert individuals from which information will be elicited and recorded in a structural and disciplined way. For example, the ORIGEN-2 simulation of the generation of radionuclides in the production reactors may be judged to yield best estimate values with an uncertainty of ±5%. Similarly, using expert elicitation, it may be determined that the inventories of individual solid waste burial grounds are best represented by a range defined by two extremes with inventories within the range being equally likely.

M. For the initial assessment, greater uncertainty in estimates will be tolerated because this is an initial analysis, and the time and resources that would be required to refine the uncertainty estimate are substantial.

N. Both the total inventory and the inventories of individual waste sites will be estimated using 100 realizations. Each total inventory realization will be used to scale a realization of the individual inventory. Each realization will maintain a mass balance. If in a single realization the fraction of inventory in one waste type is relatively high, then there must be a corresponding decrease in the fraction of inventory in one or more other waste type.

O. The SAC (Rev. 0) analysts will evaluate whether inventory realizations, when combined with release and vadose zone simulations, yield a qualitative match with the timing and magnitude of field observations from the past 55 years of Hanford Site operation (e.g., breakthrough times for near-surface disposals to the water table, cumulative mass discharged from vadose zone).

Output Display

P. Inventory analysts will be able to extract from saved simulation information - as a function of time, the disposal volume and mass (i.e., inventory) for each waste disposal simulated (e.g., liquid discharge site, solid waste burial ground) of radioactive and chemical contamination to initial disposal locations. The historical basis (1944 to present) and projection (present to site closure in 2050) shall achieve the mass balance of contaminants imported, generated, and exported from the Hanford Site. This information shall be retrievable.

Q. Inventory analysts will be able to sort the extracted inventory information and aggregate it by aggregate release area and by waste form (i.e., aggregate over time intervals the volume and contaminant mass sent to cribs, specific retention trenches, solid waste burial grounds, the ERDF trench, etc.) for each aggregate release area.

R. No specific output of this information will be automatically assembled and displayed as part of the SAC (Rev. 0); however, the ability will exist to extract this information from archived files.

3.3.3 Release

Problem Statement

A. Release simulations will produce the estimated annual release to the vadose zone from the variety of waste sites identified according to the final disposition indicated in the HSDB.

B. Existing models of release will be employed in the initial assessment.

C. Some releases are simple passthrough steps from "inventory" to "vadose zone" or "inventory" to "Columbia River" (i.e., liquid discharges to cribs, unplanned liquid releases from tanks and piping, and coolant discharges to the Columbia River). To support simulation of these passthrough releases, the following information is required to supplement the inventory: (1) physical location (coordinates) of the facility, (2) bottom elevation of disposal facility, (3) area of the facility (i.e., the areal footprint of cribs, specific retention trenches, etc.), (4) the begin/end dates of waste disposal and any duration of waste disposal or contaminant release information, (5) the leak/loss date and duration for unplanned releases, (6) remedial action to be performed, including the type of surface barrier and its design performance, and (7) the begin/end dates of remedial action, including the placement date of a surface barrier.

D. Solid waste burial grounds, the ERDF trench, and the debris from the demolition of facilities will be simulated using a soil debris release model that includes dissolution, desorption, and leachability processes. The following additional information is required to supplement the inventory: (1) soil-debris release model data, (2) physical location (coordinates) of the facility, (3) bottom elevation of disposal facility, (4) area and thickness of facility or waste (i.e., the areal footprint of wastes and the thickness of the waste), (5) the begin/end dates of disposal, (6) remedial action to be performed, including the type of surface barrier and its design performance, and (7) the begin/end dates of remedial action, including the placement date of a surface barrier.

E. Wastes encased in a cement product (e.g., concrete, grout) will be simulated using a concrete release model that has the capability of diffusion, dissolution, or leaching processes. Such a model was applied to simulate wastes disposed in concrete high integrity containers used to dispose of some low-level radioactive wastes. The following additional information is required to supplement the inventory: (1) cement release model data, (2) physical location (coordinates) of the facility, (3) bottom elevation of disposal facility, (4) area and thickness of facility or waste (i.e., the areal footprint of wastes and the thickness of the waste), (5) the begin/end dates of disposal, (6) remedial action to be performed including the type of surface barrier and its design performance, and (7) the begin/end dates of remedial action, including the placement date of a surface barrier.

F. Residual tank wastes will be simulated using a salt cake dissolution model based on nitrate salt dissolution and congruent release of other contaminants because it is the current available model. The following additional information is required to supplement the inventory: (1) salt-cake release model data, (2) physical location (coordinates) of the tank farms, (3) bottom elevation of tank farms, (4) area and thickness of tank farm waste (i.e., the areal footprint of wastes and the thickness of the waste), (5) the begin date of tank release to the environment (i.e., loss of tank integrity and initiation of leaching), (6) remedial action to be performed including the type of surface barrier and its design performance, and (7) the begin/end dates of remedial action, including the placement date of a surface barrier.

G. Releases from the graphite cores of production reactors will be simulated using the release model developed for the surplus production reactor EIS. The following additional information is required to supplement the inventory: (1) graphite core release model data (DOE 1989 1992), (2) physical location (coordinates) of the burial trench in the 200 West Area, (3) bottom elevation of the trench, (4) area and thickness of graphite core waste (i.e., the areal footprint of wastes and the thickness of the waste), (5) the begin date of the graphite core release to the environment (i.e., the date of loss of core shell integrity and initiation of leaching), (6) remedial action to be performed (i.e., one-piece removal from the 100 Areas to a burial trench in the 200 West Area), including the type of surface barrier and its design performance, and (7) the begin/end dates of remedial action, including the placement date of a surface barrier.

H. Releases from ILAW glass in the SAC (Rev. 0) will apply the glass corrosion and release model applied in the composite analysis (Kincaid et al. 1998). Within the River Protection Program, the ILAW release is currently estimated using a fully coupled, reactive, geochemistry and vadose zone transport model. This model and its forecasts will be published later this year; however, it does not directly support the probabilistic approach taken in the SAC (Rev. 0) computation. Efforts will be made to apply the earlier glass corrosion and release model to match the forecasts of the more mechanistic model.

The following additional information is required to supplement the inventory: (1) physical location (coordinates) of the ILAW disposal, (2) bottom elevation of disposal trenches or excavation (i.e., the elevation of the plane where the ILAW project will specify the released mass flux), and (3) the area and thickness of glass waste form deposit (i.e., the areal footprint of wastes and the thickness of the waste). Additional information about the disposal should be gathered. This information includes the begin date of ILAW glass disposal to the environment; the type of interim and final surface barrier(s) to be applied and its design performance; and the end date of disposal, including the placement date of surface barrier(s).

I. Releases from naval reactor compartments will be simulated using the release model applied in the performance assessment for the post-1988 solid waste burial grounds in the 200 East Area (Wood et al. 1996). Essentially, the reactor compartments are a solid waste disposal. The following additional information is required to supplement the inventory: (1) naval reactor compartment corrosion and release model data, (2) physical location (coordinates) of the burial trench, (3) bottom elevation of the burial trench, (4) area and thickness of reactor compartment deposit (i.e., the areal footprint of wastes and the thickness of the waste), (5) the begin date of disposal and release to the environment (i.e., date of the initiation of corrosion and leaching), (6) remedial action to be performed, including the type of surface barrier and its design performance, and (7) the begin/end dates of remedial action, including the placement date of a surface barrier.

J. There will be a realization of release model parameters corresponding to each of the 100 realizations of inventory.

Endpoints for Analysis

K. The Release Module will provide estimates of the volume and mass of contaminant as a function of time that is released from various waste types to the environment. The estimates will address inventory: (1) delivered to the vadose zone (e.g., discharges to cribs, ponds, trenches, reverse wells), (2) disposed in specific waste forms (e.g., in solid waste burial grounds, ILAW, naval reactor compartments), and (3) retained in facilities (e.g., canyons and tunnels). In addition to direct discharges to the vadose zone, other passthrough releases include those to the Columbia River and to the atmosphere. Data on these inventories will be tracked through the release model to simply indicate their final disposal. If possible, the time interval will be annual. If the release estimate relies on process knowledge and simulations of waste discharges, the time interval may be a function of Hanford Defined Waste model (Agnew et al. 1997) simulations and, therefore, constrained to a five-year interval. These release estimates will reflect the history and forecast of disposals from 1944 through site closure (i.e., assumed in 2050) and the following 1,000 years until 3050.

L. In some cases, the releases are assumed to occur from the time of disposal. In other cases, the releases are assumed to occur following degradation of a container, structure, or barrier. Releases are assumed to continue until the waste form is exhausted or the analysis has pasted 3050 AD.

M. Because remedial actions can and will occur at past practice sites, the cumulative release during simulation will not be a continuously increasing function. For example, remedial actions at 100 Area and 300 Area liquid discharge sites and solid waste burial grounds will result in the removal of waste from the environment and its reintroduction at the ERDF trench. Thus, simulating of cumulative release to the environment in the 100 and 300 Areas would show a decrease during remedial action, while simulation of the release to the environment at the ERDF trench would show continued increase.

Uncertainty Estimation

N. Distributions in the values of release model parameters will be defined. These distributions will be used to create a probabilistic estimate of release from Hanford Site waste types to the environment.

O. For the SAC (Rev. 0), greater uncertainty in model parameters will be tolerated because this is an initial analysis, and the time and resources required to refine the uncertainty estimate would be substantial. Such efforts are deferred to the SAC (Rev. 1).

P. The SAC (Rev. 0) analysts will evaluate whether release realizations, when combined with inventory and vadose zone simulations, yield a qualitative match with the timing and magnitude of field observations from the past 55 years of Hanford Site operation (e.g., breakthrough times for near-surface disposals to the water table, cumulative mass discharged from the vadose zone).

Output Display

Q. Release analysts will be able to extract from saved simulation information – as a function of time, the released mass flux for each waste disposal simulated (e.g., liquid discharge site, solid waste burial ground) of radioactive and chemical contamination from disposal locations. The estimated releases from 1944 until 3050 will be retrievable and shall reveal the mass balance of contaminants remaining in waste forms (inventory) and released to the environment (release) as a function of time.

R. Release analysts will be able to sort the extracted release information and aggregate it by time interval, by aggregate release area and by waste form. For example, aggregate information will be retrievable over time intervals for releases to the vadose zone from cribs, specific retention trenches, solid waste burial grounds, the ERDF trench, the ILAW disposal facility, naval reactor compartments, graphite cores of production reactors, canyon buildings and tunnels, etc.

S. No specific output of this information will be automatically assembled and displayed as part of the SAC (Rev. 0); however, the ability will exist to extract this information from saved or archived files from simulations.

3.3.4 Vadose Zone Flow and Transport

Problem Statement

A. Vadose zone flow and transport simulations will be based on (1) geohydrologic profiles and properties for aggregate release areas of the Hanford Site (i.e., portions of the 200 Areas, each 100 Area, the 300 Area), (2) estimates of deep infiltration rates resulting in contaminant migration, (3) estimates of geochemical reaction of contaminants in contact with the soils and sediments of the vadose zone profile, and (4) waste inventory and release projections.

B. Geohydrologic profile and hydraulic and transport property data will be assembled for each aggregate release area to be simulated. The vadose zone profile and property models will be one-dimension vertical columns in the initial assessment. While the initial assessment will use a one-dimensional vadose zone model, future analyses may explore the use of multidimensional models that explicitly account for structural features occurring at the Hanford Site. The current one-dimensional approach does not neglect multidimensional effects, rather it includes them in the uncertainty of the one-dimensional conceptualization and model parameters. Geohydrologic units will be identified and their thickness ranges specified for the aggregate release area. Where necessary to represent known structural features, multiple templates of the one-dimensional vadose zone column beneath an aggregate release area will be used. The range for each process model parameter will also be developed for each geohydrologic unit of the aggregate release area. Properties that will be represented include unsaturated hydraulic conductivity, water retention, dispersivity, and diffusion coefficient. Care will be taken to develop and apply correlated model parameters, where necessary, to appropriately model properties, (e.g., parameters of the van Genuchten and Mualem models [van Genuchten 1980] of unsaturated hydraulics and water retention). Data to support the vadose zone profile and property models will be assembled for each aggregate release area.

C. Infiltration rates into the waste deposits in the vadose zone are a function of the climate, the surface soils, and the vegetation. Estimates of infiltration and water table elevation for the initial assessment are dependent on the assumption of a continuation of current climate, as indicated by the recent 30-year record (i.e., 1961 to 1990) for the Hanford Site and the Pacific Northwest region. Vadose zone simulations in the initial assessment will incorporate infiltration by applying a step model of sequential infiltration events for defined periods of time. Simulations will begin with a natural recharge rate defined by the climate, the undisturbed soil profile, and original vegetation. This will be followed by an operational period when the land surface is disturbed (e.g., trenches excavated, cribs constructed, waste disposed and buried) and maintained free of vegetation. In the case of liquid discharge site and unplanned liquid releases, the operational period may be divided into two periods: one representing the operational or unplanned discharge superimposed onsite infiltration, and the second representing only the site infiltration resulting from natural precipitation.
A protective barrier period begins with construction of a surface barrier and lasts for the design life of the barrier. Finally, the degraded cover period begins after the design life of the barrier is exceeded and lasts for the duration of the analysis. Thus, infiltration will be simulated using a series of infiltration rates, including natural, operational (first and second type), protective barrier, and degraded barrier. Several protective barrier designs are being considered at the Hanford Site. Data to support the vadose zone infiltration boundary condition will be assembled.

D. The geochemical reaction of contaminants with vadose zone sediments will be simulated in the SAC (Rev. 0) using the linear sorption isotherm model. The mobility of contamination is highly dependent upon its speciation and surrounding environment. It is assumed that upon introduction to the vadose zone environment, waste mobility is dominated by waste characteristics. After being in contact with vadose zone sediments and soil water for some distance, it is assumed the waste undergoes a change in its mobility based on buffering of the contaminant solution by the vadose zone hydrogeologic units. Finally, it is assumed that once contaminants have migrated a short distance in the Hanford Site unconfined aquifer, another mobility state is defined by the highly buffered, neutralized, and diluted contaminant. For the initial assessment, distribution coefficients will be defined for each contaminant in several zones (e.g., upper [near field] vadose zone, lower [far field] vadose zone, and unconfined aquifer). Where indicated, K_d dependency on hydrogeologic units will be included. Broad ranges of distribution coefficient may be necessary to represent the suite of waste speciation and surrounding environment conditions that are possible. Data to support the vadose zone and aquifer geochemical reaction model will be assembled.

E. Analysis of liquid discharge and unplanned release sites will be conducted on a site-by-site basis whenever inventory and release data permit. This is because the superposition of liquid discharges to a single soil column results in nonrepresentative contaminant migration and release from the vadose zone. In those cases where liquid discharge sites are remediated, contamination to a prescribed elevation will be removed from the vadose zone simulation and placed in the ERDF trench. The vadose zone simulation will continue to predict the migration and fate of contamination in the vadose zone below the cleanup elevation.

F. Analysis of solid waste burial grounds will be aggregated within operational areas or aggregate release areas and simulated with a single vadose zone profile. The inventory of solid waste disposal will be increased over time until all burial grounds are closed. In some cases the simulation will account for remedial action, and in those cases fractions of the solid waste inventory will be removed during the remedial action time period. The vadose zone simulation will continue to predict the migration and fate of contamination in the vadose zone below the cleanup elevation.

Endpoints for Analysis

G. The Vadose Zone Module will provide estimates of the mass flux of contaminant as a function of time entering the water table of the unconfined aquifer. The estimates will address releases from all operational areas for the 10 radionuclide and chemical contaminants selected for the initial assessment. Estimates will be provided for individual waste sites where available (e.g., liquid discharge sites), and for aggregated sites where applicable (e.g., the combination of trenches that comprise solid waste burial grounds). Of course, the vadose zone releases to the aquifer will be aggregated to groundwater model nodes in order to introduce contaminants into the aquifer and river models.

H. The Vadose Zone Module will provide estimates of mass flux of contaminants from the vadose zone to groundwater for the period 1944 through 3050.

Uncertainty Estimation

I. Distributions of vadose zone model parameters will be defined. These distributions will be sampled to create a probabilistic estimate of release from the vadose zone to the Hanford Site unconfined aquifer and the Columbia River. Correlations among data will be developed, when necessary, to appropriately simulate hydraulic, transport, and geochemical properties.

J. For the SAC (Rev. 0), greater uncertainty in vadose zone model parameters will be tolerated because this is an initial analysis, and the time and resources required to refine the uncertainty estimate would be substantial. Efforts to refine the uncertainty estimates are deferred to the SAC (Rev. 1).

K. The SAC (Rev. 0) analysts will evaluate whether vadose zone simulations, when combined with inventory and release simulations, yield a qualitative match with the timing and magnitude of field observations from the past 55 years of Hanford Site operation (e.g., breakthrough times for near-surface disposals to the water table, cumulative mass discharged from the vadose zone).

Output Display

L. Vadose zone analysts will be able to extract from saved or archived simulation information – as a function of time, the volumetric fluid flux and mass flux released to the aquifer for each waste disposal simulated (e.g., liquid discharge site, solid waste burial ground) of radionuclide and chemical contamination from disposal locations. The estimated releases to groundwater and river from 1944 until 3050 will be retrievable and shall reveal the mass balance of contaminants remaining in waste forms (inventory), in the vadose zone (release), and released to the groundwater (vadose zone) as a function of time.

M. Vadose zone analysts will be able to sort the extracted vadose zone information and aggregate it by time interval, by aggregate release area, and by waste form. For example, aggregate information will be retrievable over time intervals for those releases to groundwater from cribs, specific retention trenches, solid waste burial grounds, the ERDF trench, the ILAW disposal facility, naval reactor compartments, graphite cores of production reactors, canyon buildings and tunnels, etc.

N. No specific output of this information will be automatically assembled and displayed as part of the SAC (Rev. 0); however, the ability will exist to extract this information from saved or archived files of completed simulations.

3.3.5 Groundwater Flow and Transport

Problem Statement

A. Groundwater flow and transport simulations will be based on the established and available Hanford Site unconfined aquifer model (Cole et al. 1997). The aquifer model is supported by the DOE and developed and maintained by the Pacific Northwest National Laboratory.

B. A transient inverse calibration method is being applied to create a model of the aquifer that is consistent with the entire body of water table elevation observations (i.e., observations from 1944 to present). A three-dimensional conceptual model has been developed and is based on the observed structural features of the aquifer (i.e., top and bottom elevations of geohydrologic strata, hydraulic connection to the underlying basalts and to the Columbia River).

C. Areal recharge from precipitation on the Hanford Site is highly variable, both spatially and temporally, and depends on local climate, soil type, and vegetation, as discussed in Fayer and Walters (1995). Using their methodology, Fayer produced an estimate of the long-term average areal distribution of recharge resulting from the sitewide variation of the controlling features and parameters. The long-term average distribution of recharge used for the groundwater model is shown in the Composite Analysis (Kincaid et al. 1998). This distribution is based on the 30-year record of Hanford Site and regional climate, and its application to the initial assessment is justified by the assumed continuation of the modern-day climate.

D. The groundwater model will be applied to simulate releases from the central plateau, the 300 Area, and the 100 Area. For the initial assessment, the analysis will provide estimated releases to the Columbia River from each 100 Area by simulation of contaminant mass flux into groundwater without simulation of dynamic groundwater mounds during the reactor operation period.

E. The geochemical reaction of contaminants with groundwater sediments will be simulated in the SAC (Rev. 0) using the linear sorption isotherm model. The methodology described in the vadose zone section above will be applied, and the development of model parameters will be done jointly with the vadose zone effort.

Endpoints for Analysis

F. The groundwater model will provide predictions of contaminant concentrations in space, and mass and volumetric flux to the Columbia River. Both will be predicted as a function of time from 1944 until 3050. The groundwater prediction for the initial assessment will include 10 radionuclide and chemical contaminants.

G. The groundwater model will address the unconfined aquifer underlying the Hanford Site south and west of the Columbia River. The upper elevation extent of the model includes the Dry Creek and Cold Creek valleys.

H. The groundwater module will provide estimates of contaminant concentrations in groundwater and mass flux of contaminants to the Columbia River for the period 1944 through 3050.

Uncertainty Estimation

I. Uncertainty within the groundwater simulation will be limited to uncertainty aspects of the model quantified by the Hanford Groundwater Project at the time of initial assessment. It is anticipated that a single conceptual model will be calibrated and available for SAC (Rev. 0) simulations. Uncertainty of the groundwater model for the initial assessment will not consider multiple conceptual models, but may consider uncertain but acceptable variability in model parameters identified during the transient inverse calibration.

Output Display

J. Contaminant concentrations will be saved at 200 locations from throughout the domain and at 200 output times. Of the 200 locations, some or all may be from the groundwater domain. These predictions of groundwater concentration will be used to evaluate human health risk and economic impacts at specific times and points of interest. The time intervals need not be equal.

K. Contaminant concentrations will be stored at 2,500 locations and at 50 steps planes to enable the plotting of areal contaminant contour plots and assessment of socio-cultural impacts. Of the 2,500 locations, all will be from the groundwater domain. The time steps will be specified before the simulation, and may not involve equal time intervals. A goal will be to also use this data for evaluating human health risk.

L. Groundwater volumetric and contaminant flux to the Columbia River will be predicted (and may be displayed) at each time step to provide the required linkage to the riparian zone and the Columbia River Modules. These groundwater model predictions will be available along the entire Hanford Site shoreline.

3.3.6 Columbia River Shore Environment

Problem Statement

A. The River Shore Module of the SAC (Rev. 0) will provide predictions of contaminant concentrations in the upper portion of the riparian zone (i.e., seep water and its associated riparian zone soil). For the SAC (Rev. 0), these will be based on predicted groundwater concentrations, predicted river water concentrations, solid-aqueous distribution coefficients, and empirical coefficients (dilution factors) that estimate relationships between groundwater and river water concentrations, and those in the upper riparian zone media (i.e., seep water and soil).

B. All river shore predictions are based on the fundamental assumption that regional climate and operation of the system of reservoirs on the Columbia River upstream of the Hanford Site continue throughout the period of analysis. Thus, the field observations that form the basis for the empirical coefficients apply throughout the period of analysis.

Endpoints for Analysis

C. The River Shore Module treats the local setting defined by the near shore groundwater and the neighboring riparian zone of the Columbia River. The River Shore Module relies on the Groundwater Module to provide groundwater contaminant concentrations, the Columbia River Module to provide river contaminant concentrations, and it produces local estimates of contaminant concentrations in seep water and adjacent soil within the upper portion of the riparian zone.

D. The River Shore Module will provide predictions from 1944 to 3050.

E. The River Shore Module will be able to provide predictions of seep water and associated soil concentrations at any point where groundwater contacts the Columbia River. Thus, for the SAC (Rev. 0), the River Shore Module will provide predictions of contaminant concentrations at selected points on the shoreline of the Columbia River between Priest Rapids and McNary Dams. Points downstream of the confluence of the Yakima and Columbia Rivers and points on a shoreline where groundwater is not modeled are also candidates for riparian zone concentration predictions in the SAC (Rev. 0); however, the model will assume the groundwater contaminant concentration is zero.

Uncertainty Estimation

F. Uncertainty in River Shore Module output will be represented in the SAC (Rev. 0) by the uncertainty in empirical coefficients defining the relationships between contaminant concentrations in groundwater, seep water, and soil. Multiple realizations of river shore predictions will be created by sampling from the distributions of empirical coefficients that define seep water contaminant concentration and distribution coefficients that define associated soil contaminant concentration.

Output Display

G. Contaminant concentrations will be saved at 200 locations from throughout the domain and at 200 output times for use in the ecological, human health, and economic modules. Both seep water and associated soil concentrations will be saved at each of the 200 locations. These concentration data will allow production of detailed concentration versus time plots. Predictions of contaminant concentrations in seeps and adjacent soils may be used to evaluate human health risk and economic impacts. The time intervals need not be equal.

H. Contaminant concentrations will be saved at 2,500 locations from throughout the groundwater domain and at 50 output times for use in the socio-cultural impact module. Both seep water and associated soil concentrations will be saved at each location and time. These concentration data will allow production of detailed concentration versus time plots. Predictions of riparian zone contaminant concentration will be available for use in evaluating socio-cultural impacts. The time intervals need not be equal.

3.3.7 Columbia River Flow and Transport

Problem Statement

A. The SAC (Rev. 0) analysis of Columbia River flow and transport for the period from 1944 to present will be based on the record of Columbia River flow from 1944 to present.

B. The period from present day until 3050 will be simulated for Columbia River flow and transport under the assumption that present day conditions of climate and river discharge continue throughout the period of interest. The existing 30-year record of regional climate and Columbia River discharge and stage will be used for the simulation.

C. The model of the Columbia River will include prediction of contaminants in river water both as dissolved phase and as suspended sediment in pore water within the riverbed, and on river sediments, including gravel and cobble host environments for spawning salmon and other aquatic species.

D. The model of the Columbia River water, sediment, and contaminant transport will be coupled directly with the ecosystem model, Ecological Chemical Exposure Model (ECEM) to provide biological transport estimates. State flux rate calculations will be developed to couple these models. For the initial assessment, only the aquatic primary producer portion of ECEM will be implemented.

E. The model of the Columbia River will be run twice: first, to calculate the contaminant concentration from background and non-Hanford contributions, and second, to calculate the contaminant concentration of the Hanford Site contribution superimposed on the background and non-Hanford contributions.

F. Contaminant release from the groundwater model to the Columbia River will be simulated over the full extent of the area covered by the groundwater module. This will demonstrate that releases from the 100 Areas, 300 Area, and central plateau can be simulated as discharging to the Columbia River. It will also provide insight into the relative magnitude and timing of releases from each aggregate release area.

G. Individual release to the Columbia River will be predicted for the strontium plume at the 100-N Area. Because of the complexity of the geologic environment and the hydrologic setting that gave rise to the strontium-90 contaminant distribution, the initial model of its migration and release to the Columbia River may be simplified and conservative. The Columbia River model will simulate receipt of this contamination at the N Springs location.

Endpoints for Analysis

H. The SAC (Rev. 0) analysis will simulate the Columbia River from Priest Rapids Dam to McNary Dam.

I. The SAC (Rev. 0) analysis will simulate for the period from 1944 to 3050.

J. The SAC (Rev. 0) analysis will simulate: background and non-Hanford contribution of contaminant concentrations; and Hanford Site contribution superimposed over background and non-Hanford contribution of contaminant concentrations.

Uncertainty Estimation

K. For the SAC (Rev. 0), uncertainty in the simulation of the behavior of the Columbia River, and its associated biotic transport system to the migration and fate of Hanford Site contaminants, will be characterized by parameter uncertainty in each of the component submodels and inputs to the river environment.

L. For the Columbia River Module, conceptual model uncertainty will be deferred until SAC (Rev. 1).

Output Display

M. Contaminant concentrations for both runs of the Columbia River module will be stored. These runs include the background and non-Hanford contribution, as well as the Hanford Site contribution superimposed over background and non-Hanford contribution. The results will be used by the risk and impacts models.

N. The river module shall be able to report temporal distributions of contaminants and ecological species important for biota contaminant transport. Contaminant concentrations will be saved at 200 locations from throughout the domain and at 200 output times to display spatial and temporal trends in media concentrations. The contaminant concentrations of interest include that of river water (dissolved phase and suspended sediment), pore water, and sediments (including those in the riparian zone and those associated with the river bed proper, both as soft bottom and cobble substrates). These outputs will be used to evaluate human health risk and economic impact. Note that human health and economic assessment are permitted to request 200 different locations.

O. Contaminant concentrations will be stored for 2,000 locations from throughout the river domain and at 200 times planes to enable estimating risks to ecological receptors and socio-cultural impacts. Contaminant concentrations of interest in the river and its sediments include solution concentrations in dissolved, suspended, and pore-water environments, and sediment concentrations in the riparian zone, and soft sediment and cobble river bed. Of the 2,000 locations, some will be paired river-lower riparian locations and others will be only river locations. The time intervals need not be equal.

P. The river module will be able to report, as a function of time and space, the contaminant flux in water and in sediment (suspended and riverbed) that is released from the model domain (e.g., released from McNary Dam).

3.3.8 Risk and Impact Assessment

There are four areas to the risk assessment and impact predictions component of the SAC: ecological risk assessment, human health risk assessment, economic impact predictions, and socio-cultural impact predictions. The conceptual models for these areas of risk assessment and impact predictions are discussed in the September 1999 Letter Report (BHI 1999).

3.3.8.1 Ecological Risk Assessment.

Problem Statement

A. The Ecological Risk Assessment Module will estimate risks from contaminants for a selected set of species and locations as a function of exposure and estimated body burdens. Species of interest will include riparian plants, riparian animals, aquatic plants, and aquatic animals.

B. The module will estimate changes in a limited set of community attributes as a function of exposure and body burden to the contaminants. This analysis will be performed after processing impacts, and will be based on typical outputs from the ECEM.

C. The module will be able to provide summary statistics of risk with regard to all realizations at a given location and time combination.

Endpoints for Analysis

D. The species of interest will be the Columbia River species as determined in the CRCIA, Part I, Section 4.1 (DOE-RL 1998a). These include the following:

- Algae: periphyton and phytoplankton
- Amphibians: Woodhouse's toad (tadpole, adult)
- Aquatic invertebrates: clams/mussels/snails, crayfish, fresh water shrimp, mayfly, and water fleas
- Birds: American coot, American kestrel, American white pelican, bald eagle, California quail, Canada goose/mallard, cliff swallow, common snipe, diving ducks, Forster's tern, great blue heron, and northern harrier
- Emergent vegetation: tule
- Fish: channel catfish, common carp, largescale sucker, mountain sucker, mountain whitefish, Pacific lamprey (juvenile), salmon (eggs, larvae, adults), small mouth bass, rainbow trout (eggs, larvae, adults), and white sturgeon
- Fungi: as a taxonomic group
- Macrophytes: Columbia yellowcress and water milfoil
- Mammals: beaver, coyote, mule deer, muskrat, raccoon, weasel, and western harvest mouse
- Reptiles: side-blotched lizard and western garter snake
- Terrestrial vegetation: black cottonwood, dense sedge, ferns, reed canary grass, rushes, and white mulberry.

E. There are two categories of impacts that will be measured in the SAC (Rev. 0) ecological risk assessment that will demonstrate an adverse impact from a contaminant to an ecological receptor. The species of interest will be the Columbia River species as determined in the CRCIA, Part I (DOE-RL 1998a). The metrics include the following:

1. Impacts on individual species will be measured by modeling the exposure of a species to a contaminant, and then comparing the dose or body burden of the species to a toxicity parameter (e.g., the lowest observed adverse effect level [LOAEL]). The results will be location and time specific, and the measure will be no effect, chronic effect, or potential acute effect (using a toxicity benchmark).

2. Impacts on ecosystems will be estimated as a post-processing function by analyzing food web impacts and adverse changes to the ecosystem structure and function. This analysis will be performed after processing impacts and will be based on typical outputs from ECEM. The ecosystem impacts will be described through an analysis of higher-level effects on the structure and function of the Columbia River ecosystem. This analysis will be based on the guild structure of the Columbia River species and on a food web of this ecosystem, which for Rev. 0 will consist of the food web in the CRCIA version of the ECEM.

   The guild structure combines Columbia River species into groups on the basis of shared aspects of lifestyle, habitat affinities, and trophic relationships. The food web identifies the consumption patterns of the primary species within this ecosystem (i.e., as aspect of the ecosystem structure).

   The analysis will use the impacts on species (as mentioned above) and be converted to relative losses of numbers (or biomass) through simple population-effect models. Effects on guild members will be tallied to provide an index of relative impact on species guilds within the Columbia River system. Effects on biomass flows within the system will be estimated using a linear algebra model. In this model, the relative consumption fraction matrix of the food web is premultiplied by abundance (kg/m^2) and an abundance reduction due to exposure (unitless), and postmultiplied by predator ingestion rate (kg prey/kg predator/day) and time of simulation (days) to obtain mass flows from each prey item to all predators (kg/m^2). Effects from different exposures will be apparent as changes in mass flows under those differing conditions over time.

F. Ecological impacts associated with the Columbia River will be based on both runs of the river module: background and non-Hanford contribution, and Hanford Site contribution superimposed over background and non-Hanford contribution.

Temporal Resolution

G. The temporal resolution for the Ecological Risk Assessment Module will be consistent with the discussion in Section 3.3.1.

H. The time step for the analysis will be five years, which is the minimum resolution desired for the initial assessment considering that contaminant concentrations are not expected to change significantly over this time step.

I. The first time step will be the year 2000, and the remainder of the time steps will be from 2050 to 3050.

Spatial Resolution

J. The spatial resolution for the Ecological Risk Assessment Module will be only associated with the Columbia River because the exposures that are being assessed in the initial assessment are mediated by the river. The portion of the Columbia River for the assessment will be from Priest Rapids Dam to McNary Dam.

K. The riparian zone along the Columbia River will also be assessed for individual species and ecosystem impacts. The riparian zone is often described as the distance from the river where a majority of the vegetation accesses river water. The Ecological Risk Assessment Module uses ECEM, which couples aquatic and riparian food webs; consequently, the 2,000 locations for the module will consist of paired river/riparian points. For Rev. 0, risks will be evaluated at two types of paired points: representative seep/springs and their associated river points, and lower riparian/river points. Data for seep/spring media concentrations will be obtained from the River Shore Module; data for the lower riparian zone points and all the river points will be obtained from the River Module.

L. The specific locations for measuring ecological impacts will be determined during the data gathering phase of Rev. 0. Criteria for selecting locations will be defined during that phase, and criteria will include such issues as current knowledge of ecological habitats, contaminant distribution, understanding of groundwater and river flow, and linkage with other risk modules.

Uncertainty Estimation

M. The inputs for the Ecological Risk Assessment Module will be allowed to vary at a time and at a location. The input variables are described further in the Software Requirements Specifications.

N. Not all outputs will be variable. Tissue concentrations, as calculated in the ECEM, will be expressed over a range. However, impacts for individuals will be a ratio of the tissue concentration to the toxicological benchmark (e.g., LOAEL), and a distribution for the benchmark will not be used in Rev. 0.

O. Further discussion on the uncertainty estimation is in Appendix F, Section F.3.1.2 of the SAC September 1999 Letter Report (BHI 1999).

Output Display

P. Outputs for the Ecological Risk Assessment Module will be similar to those used in CRCIA, Part I (DOE-RL 1998a). Impacts associated with the Columbia River will compare background and non-Hanford contribution to Hanford Site contribution superimposed over the former.

Q. Uncertainty for the Ecological Risk Assessment Module will also be displayed as a tornado diagram, which will rank order the key factors in the analysis from least to most impactful.

R. Outputs for some of the species and ecosystem in the assessment will be shown through time. The scenarios will be chosen based on criteria established in the data gathering phase.

3.3.8.2 Human Health Risk Assessment.

Problem Statement

A. The Human Health Risk Assessment Module will estimate cancer and non-cancer risks to humans from contaminants in the study region. The routes of exposure will vary based on the scenarios for the assessment. The scenarios are focused on the use of potentially contaminated water and exposure to potentially contaminated soil and sediment.

B. The module will be able to provide summary statistics of risk with regard to realizations at a given location and time combination.

Endpoints for Analysis

C. The scenarios for the Human Health Risk Assessment Module are described further in the September 1999 Letter Report (BHI 1999). Other references for the scenarios include the *Hanford Site Risk Assessment Methodology* (DOE-RL 1995) and CRCIA, Part II (DOE-RL 1998a). Scenarios describe the exposure from all pathways (e.g., ingestion, inhalation, and dermal) to environmental contaminants in the groundwater, surface water, and sediment, as well as through fish, meat, and produce that was also exposed to contaminants. The scenarios will include the following:

   1. Locations on the Hanford Site will be assessed for the Residential Farmer and Native American Subsistence User. The groundwater pathway will be the primary exposure route to the contaminants. The model will include irrigation in the Residential Farmer scenario, which will add contamination from the groundwater to the irrigated soil. At 2050, the soil concentration will be zero and will increase over time due to the contribution of contaminants from the groundwater. This portion of the model is not dynamically linked to the Environmental Transport Modules and, therefore, the mass of the contaminants will not be conserved.

   2. Along the edge of the Columbia River, the assessment will include the Ranger and the Native American Subsistence User. The primary exposure route to the contaminants is the river pathway, including surface water, porewater, and sediment.

   3. The assessment will include scenarios that use the Columbia River, which include Recreational Users (casual and avid) and Residential Farmer. The Residential Farmer will be similar to the scenario on the Hanford Site, but the exposure will be from the river pathway rather than the groundwater pathway. Also, like the scenario on the Hanford Site, irrigation will result in soil contamination.

D. Two categories of impacts, carcinogenic and systemic effects, will be measured in the SAC (Rev. 0) human health risk assessment that will demonstrate an adverse impact from a contaminant to humans. Impacts will be assessed with the HUMAN computer code that was used in CRCIA, Part I (DOE-RL 1998a). The metrics include the following:

1. Carcinogenic effects will be evaluated for the radionuclides and carcinogenic chemicals. The incremental lifetime cancer risk will be calculated using available slope factors, which assumes additivity of toxic effects from all carcinogenic contaminants. In addition, the results of the human health impact assessment will be presented as an annual dose, which is specified under DOE Orders 5400.5 and 435.1.

2. Systemic effects will be evaluated for noncarcinogenic radionuclides (e.g., the nephrotoxic effects of uranium) and chemicals. The hazard index will be calculated using available reference doses, which assumes additivity of toxic effects from all noncarcinogenic contaminants.

E. Human health impacts associated with the Columbia River will be based on both runs of the river module: background and non-Hanford contribution, and Hanford Site contribution superimposed over background and non-Hanford contribution.

Temporal Resolution

F. The temporal resolution for the Human Health Risk Assessment Module will be consistent with the discussion in Section 3.3.1.

G. The time step for the analysis will be five years, which is sufficient resolution to monitor changes in impacts through human activity within the study area.

H. The first time step for analysis will be the year 2000, and the remainder of the time steps will be from 2050 to 3050.

Spatial Resolution

I. The spatial resolution for the Human Health Risk Assessment Module will be scenario-specific. The Residential Farmer and Native American Subsistence User will be assessed on the Hanford Site using groundwater from the unconfined aquifer as the source of water for drinking, irrigation, and other activities. The Ranger, Native American Subsistence User, and Recreational User will be evaluated where exposures to the river water are appropriate in the Columbia River from Priest Rapids Dam to McNary Dam. The Residential Farmer will also be evaluated for use of river water at water uptakes located from Priest Rapids Dam to McNary Dam.

J. The specific locations for measuring human impacts will be determined during the data gathering phase of the SAC (Rev. 0). Criteria for selecting locations will be defined during that phase. Criteria will include such issues as current knowledge of ecological habitats, contaminant distribution, understanding of groundwater and river flow, and linkage with other risk modules.

Uncertainty Estimation

K. The inputs for the Human Health Risk Assessment Module will be allowed to vary at a time and at a location. The input variables are described further in the Software Requirements Specifications.

L. The HUMAN model will calculate dose from consuming contaminated fish, meat, and produce, and these values will be compared to the outputs in similar species from the Ecological Risk Assessment Module.

M. Further discussion on the uncertainty estimation is in Appendix F, Section F.3.2.2, of the SAC September 1999 Letter Report (BHI 1999).

Output Display

N. Outputs for the Human Health Risk Assessment Module will be similar to those used in CRCIA, Part I (DOE-RL 1998a). Impacts associated with the Columbia River will compare background and non-Hanford contribution to Hanford Site contribution superimposed over the former.

O. Uncertainty for the Human Health Risk Assessment Module will also be displayed as a tornado diagram, which will rank order the key factors in the analysis from least to most impactful.

P. Outputs for some of the scenarios will be shown through time. The scenarios will be chosen based on criteria established in the data gathering phase.

3.3.8.3 Economic Impact Predictions.

Problem Statement

A. The Economic Risk Assessment Module will estimate changes in:

- The value of agricultural activities and their effect on the economy
- The value of recreational activities and their effect on the economy
- Drinking water supply cost based on filtration, treatment, or replacement.

B. The module will be able to provide summary statistics of economic changes over the realizations for each selected time.

C. The change in the value of agricultural activities will be measured as changes in the quantity of product produced, revenues, producer's surplus, and cost. These changes are a function of proscription/public avoidance of agricultural products, based on an economic trigger set when the concentration in the surface water or groundwater exceeds a threshold concentration. The analysis will include 31 types of agricultural products, including produce, meat, and fish.

D. The change in the value of recreational activities will be measured as changes in the value of fishing, boating, swimming, and water skiing on the Columbia River. These changes are a function of proscription/public avoidance of recreational activities, based on an economic trigger set when the concentration in the surface water or the tissue of recreational fish species exceeds a threshold concentration.

E. The reduced value of agricultural and recreational activities are calculated and apportioned over the baseline economy. The normalized baseline economy is the percentage contribution to the overall economy from 65 industries, which are then aggregated to 35 economic sectors.

F. Alternative drinking water supply costs will be calculated by the cost of filtering or replacing the water supply at each economic location. The need for replacing the drinking water supply will be based on an economic trigger set when the concentration in the surface water or groundwater exceeds a threshold concentration.

G. Thresholds for trigger mechanisms will be determined during the data gathering phase.

H. The baseline economy used for the analysis will use currently available information from the U.S. Department of Commerce's Bureau of Economic Analysis.

I. The Economic Risk Assessment Module calculations will be based on surface water concentrations that include background and Hanford Site contributions.

Temporal Resolution

J. The temporal resolution for the Economic Risk Assessment Module will be consistent with the discussion in Section 3.3.1.

K. The Economic Risk Assessment Module will provide predictions from 2050 to 3050.

L. The time step for the analysis will be every five years, which is sufficient resolution to monitor changes in impacts through economic activity within the study area.

Spatial Resolution

M. The economic assessment is a regional assessment for Benton, Franklin, Walla Walla, and Umatilla Counties.

N. The region of the Columbia River for the economic assessment will be from Priest Rapids Dam to McNary Dam.

Uncertainty Estimation

O. Uncertainty regarding the magnitude and duration of protective actions will be addressed by developing both "best estimates" and bounding ranges for trigger mechanism parameters.

P. Uncertainty regarding costs, revenues, and nonmonetary values will be accounted for by incorporating information for variation in these measures with regard to time, space, and resource quality.

Q. Further discussion on the uncertainty estimation is in Appendix F, Section F.3.3.2, of the SAC September 1999 Letter Report (BHI 1999).

Output Display

R. The output display will show changes in economic output, employment, and wages by economic sector. These changes will be displayed over the time of the assessment. How the changes in economic output, employment, and wages by economic sector will be shown spatially will be considered during the data gathering phase.

S. The economic sectors to be modeled will be determined during the data gathering phase.

3.3.8.4 Socio-Cultural Impact Predictions.

Problem Statement

A. The Socio-Cultural Risk Assessment Module will evaluate the change in access to culturally important resources due to the presence or absence of contamination over time.

B. Culturally important resources include sacred sites, areas where cultural activities take place, and biota that are used for human consumption or in human activities. Cultural thresholds are the level of contaminant concentration that is of interest to a cultural group.

Endpoints for Analysis

C. The socio-cultural impacts will be related to groundwater contamination or contamination in the Columbia River from Priest Rapids Dam to McNary Dam. There is no terrestrial assessment in the SAC (Rev. 0) because there is no assessment of the soil or air concentrations in the environmental pathways.

D. Direct effects of contamination on resources of socio-cultural importance will be measured by the following:

   1. Acreage underlain by groundwater with contamination above cultural thresholds will be measured by the Socio-Cultural Risk Assessment Module. Cultural thresholds will be defined during the data gathering phase. The value or values for cultural thresholds will be an input parameter that will be used to generate the groundwater plume maps by the SAC software.

   2. Amount of biota with detectable contamination will be based on the results of the Ecological Risk Assessment Module and current day population estimates.

E. Indirect effects of contamination resulting from ecological, human health, or economic impacts will be measured by the following:

   1. Regions of land and the river that might be restricted in the future because of the potential for significant human health risks will be measured using the output of the groundwater contamination plumes and the Human Health Risk Assessment Module. Biotic resources that might be restricted in the future because of the potential for significant human health risks will be measured using the output of the River Module and the Human Health Risk Assessment Module.

   2. Degree of fragmentation or largest size of intact ecosystem remaining uncontaminated will be measured as a function of change in the habitats of concern in the Ecological Risk Assessment Module.

Temporal Resolution

F. The temporal resolution for the Socio-Cultural Risk Assessment Module will be consistent with the discussion in Section 3.3.1.

G. The time step for the analysis will be every 20 years, which is sufficient resolution to monitor changes in impacts within the study area.

H. The first time step will be the year 2000. The remainder of the time steps will be from 2050 to 3050.

Spatial Resolution

I. The spatial extent of the socio-cultural analysis will be the Hanford Site and from Priest Rapids Dam to McNary Dam in the Columbia River. The Columbia River riparian zone, as defined in the Ecological Risk Assessment Module above, will also be included.

J. The location of cultural resources, sacred sites, and habitats of concern that will be included in the assessment will be determined during the data gathering phase of the assessment.

K. The restriction or fragmentation of biotic resources in the assessment will be determined during the data gathering phase of the assessment.

Uncertainty Estimation

L. The uncertainty estimate for the socio-cultural assessment will be for the most part qualitative. See Appendix F, Section F.3.3.2 of the SAC September 1999 Letter Report (BHI 1999) for further discussion on uncertainty in the socio-cultural assessment.

M. Contaminant inputs for the socio-cultural assessment will vary. For example, there will be a distribution of groundwater contaminants around the cultural threshold that will be mapped and will be captured in the estimate of acreage.

Output Display

N. The acreage of groundwater contamination above the cultural threshold will be calculated at 20-year intervals.

O. The measure of ecosystem fragmentation will be shown on a map of the river.

4.0 SOFTWARE REQUIREMENTS SPECIFICATION FOR THE SYSTEM ASSESSMENT CAPABILITY (REV. 0) SYSTEMS CODE

This section contains the high-level functional requirements for the suite of computer codes that will implement the SAC (Rev. 0) analysis. Although these requirements' statements do not require existing computer codes, there is an intent to use several existing computer codes to reduce the overall development time and cost. In each case, the existing computer codes will satisfy the set of defined requirements. In several cases, the existing computer code has a broader set of capabilities than the set of listed requirements. The suite of existing codes are identified and briefly discussed in Section 5.0.

These requirements are written to define the development and assembly of an initial capability to assess sitewide risks and impacts at the Hanford Site. While it is expected that results of the initial assessment will provide valuable insight regarding waste disposals and remedial actions, it is recognized that the SAC (Rev. 0) development is a demonstration (or illustration) of what is possible. Accordingly, many of the requirements set forth represent what future decision-assisting assessments are envisioned to require, while others are set at levels that may stretch but not exceed resources. Examples of these requirements include, but are not limited to, the following:

- The number of contaminants and those specific contaminants to be simulated
- The use of an available climate record to forecast future climate
- The time period of analysis
- The number of aggregated release areas
- The number of points in space and moments in time for which contaminant concentrations are stored for risk and impact assessment
- The number and identity of ecological species
- The time allowable for completion of a probabilistic simulation.

Creation and execution of the SAC (Rev. 0), based on these requirements, will be a meaningful demonstration of the capability to perform sitewide assessments. However, it is acknowledged that all software requirements will be revisited and evaluated for completeness and rigor before the design of the SAC (Rev. 1).

4.1 GENERAL REQUIREMENTS

4.1.1 Time Period for Analyses

The software shall be capable of operating on data for the period from 1944 through 3050 inclusive (1,000 years following Hanford Site closure).

4.1.2 Transient Analyses

The software shall be able to perform transient analyses of fluid flow and contaminant transport with respect to the following environmental media:

A. Vadose zone, including movement of an inventory of contaminants in the vadose zone as a result of remediation activities

B. Groundwater

C. Columbia River.

4.1.3 Separation of Calculations

A. The software will allow running multiple ecological, human, economic, and socio-cultural impact scenarios without repeating release and transport calculations.

B. The software shall model the Hanford Site contribution to risks for the contaminants modeled.

C. The software shall provide the ability to treat a radioactive contaminant either as a radioactive material or as a chemical. To model a contaminant as both (e.g., uranium-238 as a radioactive element and uranium as a chemical) will require modeling it twice, specified each way.

4.1.4 Repeatability Requirements

The software shall produce the same output for separate runs using identical inputs that are performed on the same machine using the same operating system.

4.1.5 Impact Scenarios

A. The software shall be capable of one-at-a-time evaluation of ecological impacts scenarios.
B. The software shall be capable of one-at-a-time evaluation of human impacts scenarios.
C. The software shall be capable of one-at-a-time evaluation of economic impacts scenarios.
D. The software shall be capable of one-at-a-time evaluation of cultural impacts scenarios.

One-at-a-time implementation refers to the software's ability to simulate the impacts of a scenario independently of other scenarios, either within the same run of the software or in a different run.

4.1.6 Common Data

The software shall provide the capability to obtain common data from a single location. Common data might include the following (this list is not exhaustive, and will be completed as part of the design phase):

A. Half-lives of radioactive constituents

B. Unit conversion factors

C. Chemical properties of constituents, including solubility, molecular weight, and Henry's coefficient

D. Physical parameter values that are used in more than one major module of the software (e.g., soil bulk density, soil-water partition coefficient, and unsaturated and saturated hydraulic and transport properties).

4.2 HOST SYSTEM REQUIREMENTS

A. No specific host system is specified in these requirements, in recognition of the variety of systems the legacy codes have utilized and the possibility the system may require a distributed computing environment to meet execution-time objectives.

B. To ensure code portability, new elements of the software (i.e., other than legacy code modules) shall be written to use only the programming language American National Standards Institute standard for the language chosen (Fortran, etc.). No "extensions" (such as might be provided by various compilers or operating systems) that are not part of the American National Standards Institute standard for that programming language are permitted without the written consent of the software development team leader.

4.3 USER INTERFACE REQUIREMENTS

4.3.1 System-Level User Interface Requirements

The software will include a keyword driven interface to control overall problem definition.

4.3.2 Computational Module User Interface Requirements

A. The software shall provide a procedure (utilizing script or text control files) to allow operation of the separate computational modules by a trained user (i.e., a knowledgeable individual that has received training in the application of the software).

B. The procedure will allow trained users to execute separate modules individually.

4.3.3 System-Level Results Viewer Requirements

The software shall provide a graphical user interface to aid in extracting results (human impacts, ecological impacts, economic impacts, cultural impacts, and concentration data) for viewing, report writing, or export to external plotting software. Creation of a graphical user interface for results viewing may facilitate application and interpretation of risk and impact modules by project staff, regulators, Tribal Nations, and the public.

4.4 REPORTING REQUIREMENTS

A. The software shall log information (such as names and versions of files used, data identification labels, and version of the software) to provide complete traceability for generation of the outputs.

B. The software shall be able to compute a global mass balance for inventory, vadose zone release, and vadose zone and groundwater flow and contaminant transport modules at user-specified times.

C. The software shall be able to compute and report contaminant mass balances at user-specified times in the following model components:

   1. Inventory (representing the total global mass balance)

   2. Vadose zone release

   3. Vadose zone flow and contaminant transport

   4. Groundwater flow and contaminant transport

   5. River flow and contaminant transport

   6. Released from river flow and contaminant transport (i.e., contaminants released from McNary Dam, which is the downstream boundary of the assessment domain)

   7. Exported from Hanford Site (i.e., contaminants removed from the Hanford Site by intentional human actions; e.g., shipment of fuel or SNMs off site, or shipment of waste to the Waste Isolation Pilot Plant).

D. The software shall archive sufficient information from each run to allow identification of the sources responsible for peak impacts and risks.

E. The software shall provide the capability to extract and report data associated with a particular analysis (all realizations for a given problem). The extraction software shall provide two functions: to view values in tabular format and export data that can be imported into other software packages such as a spreadsheet, word processor, or mapping software.

F. The data extraction software shall provide the capability for the user to select specific subsets of data (concentrations and/or mass fluxes, mass balances, and impact results) and write data files for import into:

   1. Plotting software such as Excel, Gnu plot, and ArcInfo or ArcView
   2. Word processing software such as Word or WordPerfect.

4.5 DATA SIZE REQUIREMENTS

4.5.1 Number of Contaminants

The systems code shall be able to process up to 10 contaminants, each of which may be handled as either a radionuclide or as a chemical.

4.5.2 Number of Locations

A. The systems code shall be able to handle up to eight aggregated release sites for representing disposal locations from which contaminants can be introduced into the environment. Waste sites could be located anywhere on the Hanford Site model domain.

B. The systems code shall be able to handle up to 2,000 locations for ecological impact analyses in a single run.

C. The systems code shall be able to handle up to 200 locations for human impact analyses in a single run.

D. The systems code shall be able to handle up to 200 locations for economic impact analyses in a single run.

E. The systems code shall be able to handle up to 2,500 locations for cultural impact analyses in a single run.

F. The locations for each type of impact analysis (ecological, human, economic, cultural) may be different from those for other impact analyses.

4.5.3 Number of Time Steps for Impacts Analyses

A. The systems code shall be able to handle up to 200 output time steps for ecological impact analyses in a single run.

B. The systems code shall be able to handle up to 200 output time steps for human impact analyses in a single run.

C. The systems code shall be able to handle up to 200 output time steps for economic impact analyses in a single run.

D. The systems code shall be able to handle up to 50 output time steps for cultural impact analyses in a single run.

E. The times for each type of impact analysis (ecological, human, economic, cultural) may be different from those for other types of impact analyses.

4.5.4 Number of Species for Ecological Impacts

A. The Ecological Impacts Module shall support up to 60 ecological species.

4.6 CONTROL REQUIREMENTS

4.6.1 Location Selections

A. The software shall allow the user to select the set of locations where ecological impact calculations shall be performed independent of where other impact analyses are being performed.

B. The software shall allow the user to select the set of locations where human impact calculations shall be performed independent of where other impact analyses are being performed.

C. The software shall allow the user to select the set of locations where economic impact calculations shall be performed independent of where other impact analyses are being performed.

D. The software shall allow the user to select the set of locations where cultural impact calculations shall be performed independent of where other impact analyses are being performed.

4.6.2 Stochastic Control

The software shall allow the user to select the number of realizations to process within the maximum realization limit of 100.

4.6.3 Model Control

A. The software shall allow the user to select the suite of contaminants to be modeled.

B. The coding shall address classes of contaminants in such a way that modeling another similar contaminant only requires different data, but not modification of the code. A design goal (but not a design requirement) is that new software (i.e., other than legacy code modules) should be designed in such a way as to minimize or eliminate coding that is dependent on a specific contaminant.

C. The software shall allow any module in the computational sequence to be skipped if an appropriate data file is provided that provides that module's output data.

D. The software shall be designed so that failure of a realization of the inventory, vadose zone release, vadose zone flow and contaminant transport, groundwater flow, groundwater contaminant transport, river shore environment, or river flow and contaminant transport modules does not destroy results of other realizations.

E. The Environmental Stochastic Preprocessor (ESP) software shall be able to generate multiple input sets containing randomized values of stochastic variables for the following modules.

   1. Inventory
   2. Vadose zone release
   3. Vadose zone flow and contaminant transport
   4. Groundwater flow
   5. Groundwater contaminant transport
   6. River shore environment
   7. River flow and contaminant transport.

   The ESP may require, depending on design, a deterministic input data set for each module (this is likely in the case of existing software integrated into the SAC).

F. The Vadose Zone Release Module and the Vadose Zone Flow and Contaminant Transport Module shall be capable of interacting and exchanging data to model inventory transfers due to remediation actions at user-specified times.

G. The software will provide the capability to utilize multiple vadose zone flow and contaminant transport cases at each disposal location for a given realization so several upper boundary conditions and release mechanisms can be modeled at an aggregate disposal location.

H. The Groundwater Contaminant Transport Module shall be able to incorporate transient contaminant mass releases from all vadose zone flow and contaminant transport module locations.

4.6.4 Data Interface Requirements

A. To minimize unit conversion errors in the software:

1. All newly coded major modules will report outputs in SI units, but legacy (pre-existing) codes will be permitted to pass and receive values in the units the legacy code uses.

2. Data translators providing data for use by impacts modules shall convert incoming data to SI units before storing the values for later use.

3. Exceptions to reporting in SI units will be curies (Ci) for the unit of radioactivity, and rem or rad for the unit of dose, and other exceptions as approved by the software development team leader.

B. All geographic coordinates in the software will be specified in terms of the Lambert projection of the Washington State Plane, expressed in meters.

C. The systems software shall provide the capability to aggregate the results from the environmental transport modules for use in the impacts modules.

4.7 COMPUTATION TIME REQUIREMENTS

4.7.1 Computation Time for a Complete Alternative

A complete alternative is defined to mean a change in the data set that requires rerunning the entire analysis from the inventory model through the entire suite of transport models, and subsequently the impacts models.

A. The simulator must complete a limited uncertainty analysis for environmental data and provide performance information to support the design of the SAC (Rev. 1).

B. The computation time goal (not a requirement) is for a complete 1,000-year run of an alternative, including an uncertainty suite of 100 realizations for 10 contaminants, to require 30 days or less to simulate.

4.7.2 Computation Time for an Impacts Scenario

An impacts scenario is defined to mean a change in the data set that only requires rerunning an impact model, but does not require rerunning inventory, release, or transport models.

A. The simulator must complete a limited uncertainty analyses for impacts and provide performance information to support the design of the SAC (Rev. 1).

B. The computation time goal (not a requirement) for an assessment of a single risk and impacts scenario, including an uncertainty suite of 100 realizations, is one day. This risk and impact scenario would be based on an archived simulation of the environment.

4.8 MATHEMATICAL MODELS

4.8.1 Inventory Module Mathematics Requirements

The inventory module shall:

A. Track all radiological activity and chemical mass of concern with respect to initial disposal location and waste form category within the total system software on a historical basis (i.e., from 1944 to the present).

B. Track all radiological activity and chemical contaminant mass of concern with respect to initial disposal location and waste form category within the total system software on a projected basis through site closure (i.e., from the present until 2050).

C. Account for radioactive decay.

D. Obtain specification of the contaminants to be modeled in a particular run from the simulation control software (i.e., from the common data for a simulation).

E. Impose a sitewide total inventory limit by radionuclide and/or chemical by normalizing the inventories on a wastestream basis at a single specified time.

F. Allow the user to specify imports and exports of contaminants to and from the site on an annual basis (January 1 basis).

G. Perform mass balance calculations at user-specified times for reporting purposes.

H. Obtain specification of the vadose zone release locations to be modeled from the simulation control software.

I. Allow the user to specify a mapping of inventory types and locations into vadose zone release locations as a function of time (annual, January 1 basis).

J. Provide contaminant mass or activity disposed annually (January 1 basis) at each vadose zone release location and for each waste form category to the vadose zone release module annually.

K. Accept information about inventory as a sequence of disposal actions on a wastestream-by-wastestream basis.

L. Inventory information for a wastestream shall include the following:

1. Time of action
2. Concentration (stochastic)
3. Volume (stochastic).

4.8.2 Vadose Zone Release Module Mathematics Requirements

The Vadose Zone Release Module shall:

A. Accept contaminant mass inputs to simulated disposal locations and waste form categories on an annual basis (January 1 basis) from the inventory module for the period beginning in 1944 and ending at site closure.

B. Compute the release to the vadose zone, with respect to time, of contaminants from six waste categories:

1. Soil-debris (refer to Equation D.28 and following in Kincaid et al. [1998])

2. Cake/sludge (refer to Equation D.45 and following in Kincaid et al. [1998])

3. Glass (refer to Equation D.52 and following in Kincaid et al. [1998])

4. Cement (refer to Equation D.61 and following in Kincaid et al. [1998])

5. Reactor block/reactor compartment (refer to Equation D.64 and following in Kincaid et al. [1998])

6. Direct discharge of liquid to the soil.

C. Track inventory for each modeled disposal location handled by the software, including inventory remaining at each modeled disposal location, as well as inventory released per year (January 1 basis).

D. Accept contaminant mass inputs from the Vadose Zone Flow And Transport Module to the inventory remaining of any modeled disposal site resulting from user-specified remediation action specified for any year (January 1 basis).

E. Be able to transfer all, or a fraction, of the inventory remaining of any modeled disposal site to any other modeled disposal site in response to user-specified remediation actions for any year (January 1 basis).

F. Export actions (removal of contaminant mass offsite, e.g., to the Waste Isolation Pilot Plant) will be treated in the model as removal to a nonreleasing ("export") site, but will still be tracked within the model following removal. Up to five separate export sites will be allowed. If five are not sufficient to provide unique identification of exports, then some will be aggregated.

4.8.3 Vadose Zone Flow and Contaminant Transport Module Mathematics Requirements

The Vadose Zone Flow and Contaminant Transport Module shall be able to:

A. Numerically solve transient, sequentially-coupled partial differential equations for water mass conservation (e.g., refer to Equation 3.2.1 in White and Oostrom [1996]) and dilute species contaminant mass conservation (e.g., refer to Equation 3.7.1 in White and Oostrom [1996]) equations in variably saturated and fully saturated porous media.

B. Simulate flow and transport in at least one dimension.

C. Simulate transient contaminant release boundary conditions.

D. Simulate transient liquid-phase boundary conditions to represent a time-dependent recharge rate at a boundary, and a variable liquid-pressure boundary to represent a variable water table elevation.

E. Calculate and report the inventory of contaminant(s) in a user-specified portion of the model domain, and “zero out” or reduce contaminant concentrations to a specified level in the specified portion of the model domain at user-specified times (by year, January 1 basis) to represent soil remediation actions.

F. Report the mass flux of each contaminant at each vadose zone release location to the saturated zone for export to the Groundwater Contaminant Transport Module.

4.8.4 Groundwater Flow Module Mathematics Requirements

Groundwater flow and groundwater contaminant transport will be handled separately in the software to enable an independent simulation of water table rise and fall. The Groundwater Flow Module shall be able to:

A. Numerically solve the partial differential equation governing transient groundwater flow in two or three dimensions for isothermal, constant density fluids for a spatially distributed description of groundwater flow in the unconfined aquifer over the extent of the Hanford Site that lies west and south of the Columbia River (e.g., refer to Equation 3-17 in CFEST [1996]).

B. Simulate an unconfined water table and simulate water table elevation decline or rise in response to variable recharge conditions (for purposes of simulating water table changes related to the Hanford Site production period, but not for projected future changes; see Section 4.9.3).

C. Simulate all Hanford Site transient artificial sources and sinks.

D. Simulate spatially variable natural recharge.

E. Simulate transient pump-and-treat remediation activities.

F. Report groundwater elevation and flux rates at user-specified locations.

G. Export groundwater flow field information to a file or files suitable for use by the Groundwater Contaminant Transport Module.

4.8.5 Groundwater Contaminant Transport Module Mathematical Requirements

Groundwater flow and groundwater contaminant transport will be handled separately in the software. The Groundwater Contaminant Transport Module shall:

A. Numerically solve the partial differential equation governing transient dilute species mass transport in two or three dimensions for the unconfined aquifer over the extent of the Hanford Site west and south of the Columbia River (e.g., refer to Equation 3-18 in CFEST [1996]).

B. Accept transient contaminant mass flux inputs at multiple, variable geographic locations represented as either point or area sources.

C. Be able to simulate first-order decay and linear sorption for contaminant mass transport.

D. Report concentrations (with respect to aquifer elevation and hydrogeologic unit) at groundwater wells at user-specified locations.

E. Report contaminant mass release rates to the Columbia River boundary with respect to time and location.

F. Import and utilize groundwater flow fields exported by the Groundwater Flow Module.

4.8.6 River Shore Environment Module Mathematics Requirements

The River Shore Environment Module shall:

A. Compute and provide the following for river shore locations on the Hanford Site:

   1. Concentrations in seep water (groundwater seepage face boundaries flowing to river) from the concentration in groundwater using the following equation: $C_{seep} = (Df_{seep} \times C_{gw}) + ((1 - Df_{seep}) \times (C_{river})$.

   2. Concentrations in the upper riparian zone soil as a function of time from the concentration in groundwater using the following equation: $C_{soil} = K_{d|soil} \times C_{seep}$.

B. Export concentrations for use by the ecological, human, economic, and socio-cultural impacts module (the locations and times required by these modules will not necessarily coincide).

4.8.7 River Flow and Contaminant Transport Module Mathematics Requirements

The River Flow and Contaminant Transport Module shall:

A. Have the following capabilities:

1. Numerically solve governing partial differential equations for two-dimensional depth averaged and/or one-dimensional cross-sectional averaged flow and transport in an unsteady river environment for the following processes:

    a. Hydrodynamics (water velocities and water surface elevation)
    b. Sediment transport in a river system
    c. Contaminant transport in a river system
    d. Biotic transport in a river system
    e. Sediment-contaminant interaction, including suspended sediments and bed sediments
    f. Account for contaminant concentration variations in a vertically-layered river bed.

2. Be able to accept contaminant influxes to a vertically layered river bed, as generated by the Groundwater Contaminant Transport Module.

3. Be able to accept mass flux or concentration time series inputs generated by the Groundwater Contaminant Transport Module.

4. The equations to be solved are those documented for the MASS2 and MASS1 models in Richmond et al. (1999a, 1999b) and Richmond and Perkins (1999).

B. Estimate spatial and temporal distribution of the following:

1. Contaminants in the Columbia River water column

2. Contaminants in the sediments on and below the river bottom

3. Contaminants in biota as they contribute to contaminant transport in the form of biological debris.

C. Compute and report for use in the human and ecological impacts modules the following concentrations for the river environment of the Hanford Site:

1. Concentration in river bottom, pore water in the boundary-layer sediments and cobbles

2. Concentration in the soft river-bed sediments

3. Concentration in river water

4. Bio-available concentration in sediment pore water (assumed to be K_d adjusted by AVS/SEM or other calibration data).

D. Be able to report contaminant mass balance in terms of contaminant flux in water, in sediment, and released from the model domain downstream for user-specified times.

E. The biotic transport model will calculate the mass flux of contaminant due to biotic processes using a model of the form:

$$M_{species} = C_{species} \times Biomass_{species} \times Biomass_{produce}$$

where:

$M_{species}$ = Mass flux of a contaminant available for transport in a given time interval (Ci per square meter per year or kg per square meter per year)
$C_{species}$ = Concentration of a contaminant in a species (kg contaminant/kg body mass or Ci/kg body mass)
$Biomass_{species}$ = Standing biomass for a species (kg body mass per square meter)
$Biomass_{produce}$ = Production/death biomass transfer rate of a specie (1/year).

1. Calculation of the tissue concentration of a contaminant in the biota transport species shall use the pathway calculations provided in the ECEM code.

2. Calculation of the tissue concentration of a contaminant in the biota transport species shall be performed on a seasonal basis (4 times per year).

4.8.8 Ecological Impacts Module Mathematics Requirements

The Ecological Impacts Module shall:

A. Implement the functionality of the equations listed in Appendix A, Ecological Module Mathematical Formulations.

B. Be able to accept concentrations in media reported by the following:

1. Groundwater Module
2. River Shore Environment Module
3. River Flow and Contaminant Transport Module.

C. Generate body burdens for riparian plants, riparian animals, aquatic plants, and aquatic animals.

D. Be able to compute effects from radionuclides, organic and inorganic chemicals, or compounds.

E. Provide an estimate of an organism's average exposure once the ecosystem has reached equilibrium with the contaminants within it.

F. Be able to report, in human-readable form or electronic media, the estimated risk values as a function of analyte, species, and location.

G. Have the capability to provide summary statistics of risk from all realizations at a location.

H. Be able to generate an optional output file containing tissue concentrations or body burdens for all realizations for selected combinations of locations, species, and analytes.

4.8.9 Human Health Impacts Module Mathematics Requirements

The Human Impacts Module shall:

A. Implement the functionality of Equations 6.1 through 6.6, as documented in DOE-RL (1996c).

B. Calculate food product concentrations for the following foods, using the equations provided in Napier (1996).

1. Fish
2. Leafy vegetables - unirrigated
3. Leafy vegetables - irrigated
4. Root vegetables - unirrigated
5. Root vegetables - irrigated
6. Meat (livestock and wild game)
7. Birds (livestock and wild game).

C. Calculate food product concentrations for milk using a transfer factor relating cow food intake to milk concentrations.

D. Calculate impacts on an annual basis, assuming constant environmental concentrations throughout the entire year.

E. Be capable of one-at-a-time (see requirement 4.1.5) implementation of the human exposure scenarios defined in DOE-RL (1996c).

F. Be able to report the estimated risks and impacts for humans as a function of the following:

1. Analyte type
2. Exposure pathway (pathways are ingestion, inhalation, and external or dermal).

G. Have the capability to provide summary statistics of risk and impact from all realizations at a location.

H. Calculate population dose and risk from radioactive contaminants using a drinking water only pathway for surface water ingestion:

   1. Population size will be time-invariant
   2. Population size can be different at each human impacts output location.

4.8.10 Economic Impacts Module Mathematics Requirements

The Economic Impacts Module shall:

A. Implement the functionality of the equations given in Appendix B of these requirements.

B. Model economic impacts as a change in the regional economy given in Appendix B of these requirements.

C. Estimate the economic value and impact of public avoidance of products by modeling field crops, vegetables, tree fruit and grapes, and livestock and dairy as the target product categories.

D. Model the economic value and impact of public avoidance of recreational activities; the activities to be used in this model are fishing, water skiing, boating, and swimming.

E. Evaluate the economic cost of alternative water supplies; the model will estimate the annual cost of water filtration and the annualized cost of a replacement source.

F. Calculate all outputs as annual impacts based on present-day economic conditions.

4.8.11 Cultural Impacts Module Mathematics Requirements

The Socio-Cultural Impacts Module shall:

A. Calculate concentrations of contaminants at user-specified locations for use in the socio-cultural impacts models.

   1. The set of locations for use in the Socio-Cultural Impacts Module does not have to coincide with the locations for the Human Impacts or Ecological Impacts Modules.

   2. If a transport model has multiple layers at the location of interest, the maximum concentration of the different layers shall be utilized.

3. Concentrations are required for the following media if they are present at the specified location:

   a. Groundwater
   b. Surface water
   c. Sediment.

B. Be able to provide data necessary to produce a concentration map of locations where a contaminant concentration is above a user-specified threshold.

C. Be able to produce data for a map showing locations where the concentration of any one or more of several user-specified contaminants are above a set of user-specified thresholds, allowing for a different threshold for each contaminant.

D. Be able to calculate the areal extent where concentrations in surface water, river sediments, or concentrations in groundwater underlying soil, are above user-specified thresholds.

E. Be able to identify locations where the body burden of specified species is above a user-specified threshold level.

   1. The Ecological Impacts Module shall be used to calculate the body burdens.

   2. The locations for this body burden calculation shall coincide with the locations utilized for the Ecological Impacts Module rather than the set of locations specific to the Socio-Cultural Impacts Module.

4.9 ITEMS OR PROCESSES NOT SUPPORTED

As noted in the introduction to this document, the SAC has generated significant interest in the community for several years. This section is included to help manage the expectations of what the SAC (Rev. 0) will actually be able to compute.

4.9.1 General Concepts Not Supported

A. Modeling of background will be limited to the river transport model and subsequent impacts calculations. Background contaminants will not be modeled in the inventory, release, or groundwater transport models.

B. The release, transport, and impacts modules handle first-order decay of radionuclides, but radioactive chain decay will not be modeled except internal to the inventory module.

C. The release, transport, and impacts modules handle simple degradation of chemicals, but modeling of the resulting chemical degradation products will not be supported.

D. The software is not required to read directly from any database containing site or contaminant information.

E. The data extraction software is not required to directly invoke other software such as word processors or plotting packages.

F. The software will not model impacts to mobile receptors. For example, dose to a coyote at a location assumes the coyote spends the entire year at the specified location.

G. The software will not model inadvertent human intrusion into waste forms or trespass onto disposal sites.

H. The upland terrestrial environment will not be modeled.

I. The software is being designed to run on one or a combination of machines or operating systems; it is not required that it run without modification on other platforms or operating systems.

J. The software will not provide internal graphical support for viewing results; interpretative graphics for results will be supported by export capability suited to use with commercially available spreadsheet and graphics software.

K. Multiple contaminants may be modeled in a run of the systems code, but interaction or synergism between the contaminants will not be modeled.

L. Airborne impact pathways will not be modeled.

M. Surface water modeling will be limited to the Columbia River, no additional overland water pathways are modeled.

N. External radiation (e.g., ground shine) will not be modeled.

4.9.2 Inventory Aspects Not Supported

A. The Inventory Module will not account for neutron-induced production of tritium in tank wastes.

B. The Inventory Module will not model chemical reactions that modify the chemical properties of contaminants.

C. The inventory model will be a tracking and decay model, but will not have the ability to estimate radionuclide production or chemical compound generation.

D. The Inventory Module will not support site-specific estimates of unplanned releases or liquid discharge sites that have unknown inventories, rather, these will be estimated as aggregate values.

E. The inventory model will not explicitly model actions such as waste transfers between facilities or tanks, rather it will accept information about movement to locations that will become release points.

4.9.3 Contaminant Transport Aspects Not Supported

A. The contaminant transport modules use a linear (K_d-type) approach to chemical sorption; geochemical reactive transport phenomena are not modeled.

B. Biological decay or chemical transformation necessary to evaluate the ammonia-nitrate-nitrate chain and the degradation of carbon tetrachloride to chloroform will not be modeled in the transport pathways.

C. Intrusion by human beings, the roots of vegetation, or burrowing animals or insects into waste forms will not be modeled.

D. The formation and movement of colloids will not be modeled.

E. Although it may be accounted for to maintain appropriate mass balance in liquid-phase transport, gas-phase transport will not be directly modeled. Because the SAC (Rev. 0) excludes terrestrial ecology and atmospheric pathways, simulation in Rev. 0 is restricted to aqueous phase transport in vadose zone, groundwater, and river environments. This will provide a limited assessment capability for carbon tetrachloride, which is known to be a volatile compound.

F. The removal of contaminants from soil to another location will be modeled; however, the soil properties will be modeled as constant at the removal location (e.g., soil moisture content will not change as a result of remediation activities).

G. The unconfined aquifer’s water table elevation change will be used to define the lower boundary of the vadose zone flow and transport model domain, permitting a transient vadose zone domain. However, this feature is strictly limited to representing changes in the water table elevation at vadose zone model locations during and following the Hanford Site’s production phase (when liquid discharges had a strong influence on the aquifer). This feature will not support representation of future water table changes associated with scenarios of future land use or climate change. Residual vadose zone contaminate mobilization due to future water table rise is not a supported feature of this systems code revision.

H. The river flow and contaminant transport capability will not include the capability to handle extreme events such as dam removal.

I. The mass transfer sequences groundwater - plant - soil - terrestrial species - river or river species - terrestrial biota are not modeled in the river flow and contaminant transport capability.

J. Pump-and-treat remedial actions for groundwater contaminants and vapor extraction remedial actions for the vadose zone are not modeled as part of the initial assessment.

K. The groundwater and river shore models will not support analyses of river-stage change or bank storage effects. An empirical approach is taken to estimate dilution and mixing in seep water adjacent to the Columbia River.

4.9.4 Ecological Impacts Not Supported

A. The entire food web for a species will be assumed to reside at a single location; wide-range food consumption patterns will not be supported except as a post-processing function.

B. Feedbacks between contaminant concentrations and ecological functions are not supported (e.g., prey supply is invariant with respect to contaminant concentrations).

C. Ecological calculations will pertain only to individuals; no population calculations will be performed.

D. Ecosystem productivity calculations will not be performed.

E. The Ecological Impacts Module will be a steady state, chronic exposure model; concentration changes on less than an annual basis will not be supported.

4.9.5 Human Impacts Aspects Not Supported

A. Food items for human consumption will be assumed to have been grown at the location the exposure is being calculated; no transport of food items is modeled.

B. The software will not allow the living location of an individual to change with time (i.e., individual calculations will be limited to a single location).

C. Food items consumed by humans will have food concentrations estimated directly in the human risk code rather than using biota concentrations from the ecological code.

D. The Human Impacts Module will be a chronic exposure model; it will not accept concentration changes on less than an annual basis.

4.9.6 Economic Impacts Not Supported

A. Future economic regimes will not modeled; all economic analyses will be presented as perturbations about the present-day economy.

B. The Economics Impact Module will not address business recruitment in Rev. 0.

C. No economic impacts will be modeled outside Benton, Franklin, Walla Walla, and Umatilla counties.

D. The Economics Impact Module will not address effects from human health or socio-cultural risks. Human health risks will be addressed indirectly through regulatory standards, which are based on health effects.

E. The proportions of labor, capital, and other inputs purchased by each industry are fixed. This means that all responses to changes in final demand are proportional to the size of those changes. No accounting is made for unemployed resources or excess capacity.

F. The model assumes that all resources required for an economic expansion are either immediately available within the region of interest or can be immediately imported. No provision is made to estimate impacts if these assumptions are invalid.

G. Currently, the model is designed for "one-shock-at-a-time" analysis. If the analyst wants to evaluate the impacts of several concurrent events/shocks/activities in the economy, each must be analyzed as an individual scenario and the results across all of the scenarios aggregated to estimate the net effect.

4.9.7 Socio-Cultural Impacts Not Supported

A. No estimates of the quality of life or cultural integrity will be calculated.

B. Society and culture will be modeled as fixed for the analysis period; no evolution of society or culture will be modeled.

5.0 SYNOPSIS OF THE SYSTEM ASSESSMENT CAPABILITY (REV. 0) COMPUTER CODE DESIGN

5.1 OVERVIEW

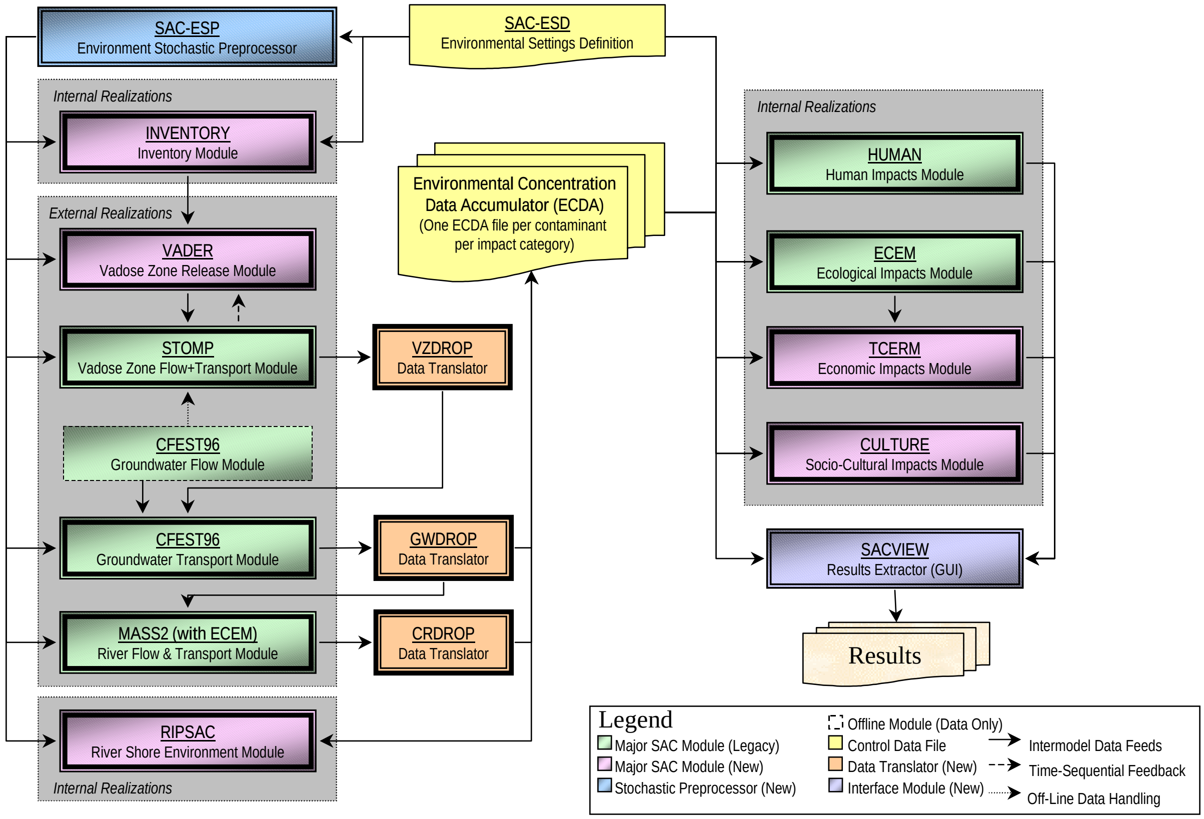
The SAC Systems Code is a tool used to model the migration of contaminants released to the environment on the Hanford Site, and assess the potential impacts of the contaminants, including ecological, human health, economic, and socio-cultural impacts. The system of codes includes existing computer programs, new computer programs, electronic data libraries, and data formatting processors (or data translators). The relationships among code modules that comprise the structure of the SAC Systems Code are illustrated in Figure 5-1.

Five categories of modules are illustrated in the flow diagram. The control and data modules are shown in yellow; major modules written for the SAC are shown in pink; pre-existing (or legacy) modules are shown in green; data translators are shown in orange; and other processors are shown in blue and purple. Major modules appearing on the left side of the diagram perform inventory and transport calculations providing estimates of the concentrations of contaminants in various media. Modules shown on the right perform calculations related to impacts from the contaminated media. Impacts include potential effects on human health, the ecology of the area, the economy of the region, and the social and cultural resources.

The general approach to handling uncertainty in the SAC (Rev. 0) is a Monte Carlo approach. Conceptually, one generates a value within a specific range for every stochastic parameter in the model (the entire sequence of models from inventory through transport and impacts) and then executes the model, obtaining an output. This process is often called one realization. One then repeats the entire process, obtaining another output that is different from the first, but equally likely to occur. After repeating this process a number of times, one has a set of equally similar outputs that represent the statistical distribution of all outputs. Several specialized sampling techniques were developed to reduce the number of realizations required in a Monte Carlo analysis to obtain a satisfactory description of the output distribution. One of the techniques, called Latin Hypercube Sampling (Iman and Conover 1982), has proven successful for mass transport applications in groundwater systems. The general Monte Carlo approach still applies, and the specific values of the input parameters are chosen from the same statistical distributions, but the sampling scheme spreads the values in such a way as to reduce sampling variability while also supporting a correlation structure between input variables.

The general objectives of the overall system assessment are met by the design. It is apparent that the SAC addresses uncertainty predictions and includes risk and impact modules for ecology, human health, economic, and culture. While not explicit in the brief design descriptions, each software module is designed to address radioactive and chemical contaminants, a 1,000-year analysis, and releases from each of the major operational areas. The groundwater modeling capability, being multidimensional, will satisfy the requirement to predict groundwater plumes. Thus, the general objectives are met.

Figure 5-1. Top-Level Code Modules and Data Interfaces.



The SAC computational tools will be assembled, written, modified, and tested under a configuration control system for software development. The SAC (Rev. 0) tools will be established under the good practices standard for quality assurance of the Pacific Northwest National Laboratory. During development, technical documentation of each software module will be maintained. Documentation of the capability will be presented in the test and evaluation document prepared next year.

As noted in Section 4.0, the requirements could be satisfied by a number of codes; however, there is an intent to use existing codes with which the project staff are familiar. This familiarity will expedite any necessary code changes and especially the development of code linkages. Existing codes that meet the software requirement of Section 4.0 for their respective modules are the following:

- STOMP for the vadose zone
- CFEST96 for groundwater
- MASS2 for the Columbia River
- HUMAN for risk to human health
- ECEM for risk to the riparian zone and aquatic ecology.

5.2 CONTROL AND DATA MODULES

The SAC (Rev. 0) software design will separate environmental analysis from impacts analysis, with coupling occurring through an "Environmental Concentration Data Accumulator" (ECDA). Two important reasons exist for this basic design feature. First, environmental analyses are detailed calculations that are expected to take on the order of one month of time to obtain from computer simulation. Impacts analyses calculations, in contract, will be much faster. Second, several different impacts scenarios may be examined from one set of environmental analyses results; given the time required to solve the environmental analyses calculations, it would be inefficient to require an identical solution for each new impact analyses.

In general, a SAC Environmental Settings Definition (ESD) file will be the principal user input to control a SAC (Rev. 0) simulation. The SAC-ESP will use information in the ESD to create/modify input files for the environmental modules (left side of Figure 4-1) and direct execution of the various computer programs to perform the environmental analyses. Three data translators (VZDROP, GWDROP, and CRDROP) will be used to assist in accumulation and redistribution of results between legacy codes used as environmental modules. Ultimately, the environmental modules and the data translators will record concentrations of analytes in certain environmental media (e.g., river surface water or groundwater) at needed locations and times to the ECDA files.

The environmental concentrations recorded in the ECDA files become the principal input to the impacts modules (right side of Figure 5-1). A data translator, SACVIEW, will then provide a user interface to examine and extract results from the impacts modules and from the ECDA files.

5.2.1 Environmental Settings Definition, SAC-ESD

The ESD file (SAC-ESD) contains the run-specific information used throughout the modeling. This file is used by the SAC-ESP and the impacts modules. The SAC-ESD provides data that describes the Hanford Site cleanup scenario and environmental conditions. Examples of information in this file include the following:

- Definition of aggregate release sites
- Selection of analytes for analysis and their physical properties
- Specifications of the times at which mass balance will be computed
- Definition of the period simulated
- Definition of the times and locations where impacts calculations can be performed
- Other parameters, which are defined using keywords.

This file is an American Standard Code for Information Interchange data file that uses a keyword-type internal format.

5.2.2 Environmental Concentration Data Accumulator Module, ECDA

The ECDA Module is not a code, but rather is a file structure definition and associated code fragments that can be used in other SAC modules to retrieve and store data in the ECDA files. The ECDA provides a central storage for all concentrations of contaminants at environmental locations and times needed to perform impacts calculations. This time history of contaminants in the environment is used to evaluate consequences of various land- and resource-use scenarios.

The ECDA will consist of a collection of binary files, with one file per contaminant per impact category. Several new code fragments will be developed to provide other SAC modules with a standard means to:

- Locate desired data in the ECDA files
- Write new data to the ECDA files
- Read data from the ECDA files.

Use of random-access binary files will provide the capability to quickly retrieve the information for a single impact calculation at a location and a time without having to read and discard the data for other locations and other times.

5.3 DATA PROCESSING UTILITIES

Auxiliary data processors include a stochastic pre-processor and a graphical interface module to extract specified subsets of the calculated results.

5.3.1 Environmental Stochastic Preprocessor, SAC-ESP

Each Release, Flow, and Transport Module contains variables that will be modeled as stochastic (individual values will be generated from a statistical distribution). The stochastic variables for each process are described in Appendix C. The user will be able to select a statistical distribution and its associated parameters (e.g., normal distribution with a mean and standard deviation) for each stochastic variable.

The SAC-ESP is a new computer code being implemented as a stand-alone executable that handles the stochastic input parameters used by the release, flow, and transport modules. The SAC-ESP is being written in Fortran 95, and it will also provide simulation control information for the release, flow, and transport modules.

5.3.2 Results Extractor, SACVIEW

The Results Extractor Module, SACVIEW, will be used to retrieve data from impact modules, based on user selections. SACVIEW is designed as a user-friendly interface to extract data in a suitable format to create tabular and graphical results using third-party visualization software. This module is a new code being written in Visual Basic, Version 6.0.

5.4 INVENTORY, RELEASE, AND TRANSPORT MODULES

5.4.1 Inventory Module, INVENTORY

The inventory model, INVENTORY, aggregates waste disposal activities into selected physical areas consistent with the input needs of the vadose zone transport analysis. INVENTORY provides the Vadose Zone Release Module with a time series of annual disposal amounts from 1944 until Hanford Site closure (~2050) that is used to model the contamination in the subsurface environment.

The INVENTORY model is a new code being written in Fortran 95. This code will require only one execution to provide the time series of inventory actions for all contaminants and stochastic realizations.

5.4.2 Vadose Zone Release Module, VADER

The vadose zone release (VADER) program receives the contaminant inventories output by the INVENTORY module and calculates release quantities. For a single realization of inventory of each contaminant at each site, VADER calculates annual contaminant releases into the vadose zone on an annual basis over the specified time period (e.g., each year from 1944 through 3050) according to specified release models and single-chain radioactive decay. The VADER program handles liquid discharges on a pass-through basis and calculates the balance of inventory remaining at the site on an annual basis. VADER also accounts for projected waste transfers resulting from remediation efforts. VADER writes the release rate data in curies/year or kilograms/year into files to be read by the next processing step, the Vadose Flow and Transport Module (STOMP).

VADER is a new computer code being written in Fortran 95. A separate execution of VADER will be required for each stochastic realization for each contaminant at each site. Stochastic variability of parameters in the release models are generated by the ESP and passed to VADER via input keyword files.

5.4.3 Vadose Zone Flow and Transport Module, STOMP

The Vadose Zone Flow and Transport Module will provide the capability to calculate release rates of contaminants from the vadose zone to groundwater. Stochastic variability of certain input parameters used by the Vadose Zone Flow and Transport Module will be generated and passed off by the ESP. The Vadose Zone Release Module will provide release rates of contaminant mass (and liquid flux for liquid discharges) that will serve as an input to this module. The mass release rates computed by this module will become input for the Groundwater Transport Module. An indirect link from previously computed groundwater flow simulations will provide the capability to model a time-varying water table elevation.

The capability in the Vadose Zone Flow and Transport Module is provided by the legacy code STOMP (White and Oostrom 1996). This code is written in Fortran (Fortran 77 and Fortran 90 source code is available) and requires only minor modifications to interface with the rest of the SAC modules.

5.4.4 Groundwater Flow Module, CFEST96

The Groundwater Flow Module will not actually invoke an executable code in the SAC (Rev. 0). The CFEST96 program (CFEST 1996) running the fully three-dimensional Consolidated Sitewide Groundwater Model will be run in advance of a SAC simulation to solve for groundwater flow. The resulting time-varying groundwater flow results will be provided for use by the SAC as a set of stored data files. As a prior simulation of the groundwater aquifer, this model will not include a probabilistic representation of infiltration and, hence, aquifer recharge. Accordingly, this approach does not enforce consistency of infiltration rate between the vadose zone and groundwater models. If the inconsistency is observed to be great, the initial assessment will not be able to exercise a probabilistic representation of infiltration in the vadose zone. Inclusion of a probabilistic infiltration in the vadose zone module allows testing of its relative importance by examination of predicted flux to the water table in two cases; with and without a probabilistic infiltration.

The Groundwater Flow Module must provide two outputs to other SAC modules. These outputs are the groundwater elevation at specific locations for use by the Vadose Zone Flow and Transport Module, and groundwater flow velocities for use by the Groundwater Transport Module in simulating contaminant transport in the unconfined aquifer.

5.4.5 Groundwater Transport, CFEST96

The Groundwater Transport Module will provide the capability to calculate transport of contaminants in the unconfined aquifer following release from the vadose zone to groundwater. A legacy code, CFEST96 (written in Fortran 77) will be used for this module. Stochastic variability of certain input parameters used by the Groundwater Transport Module will be handled by the SAC-ESP. The VZDROP data translator module will provide release rates of contaminant mass computed by STOMP (the Vadose Zone Flow and Transport Module) that will serve as an input to the Groundwater Transport Module. Groundwater flow field information (flow velocities, etc.) will be provided by the Groundwater Flow Module. The GWDROP data translator module will extract needed data from the Groundwater Transport Module results. Groundwater Transport Module results will be required to report groundwater concentrations to the ECDA (and indirectly to the River Shore Environment Module) and to report contaminant mass and fluid flux rates at the boundary between the Hanford Site unconfined aquifer and the Columbia River.

A separate effort is underway to enhance CFEST96 with a new capability to extract flow-field information from the top saturated nodes in a fully three-dimensional flow model to define a two-dimensional transport model. This “three-dimensional flow model conditioned two-dimensional transport model” is expected to provide the ability to model groundwater contaminant transport in the Hanford unconfined aquifer on the order of a few hours of computer time for a single contaminant, single realization simulation while preserving acceptable accuracy in predictive capability. Classic two-dimensional modeling has historically produced unacceptable accuracy (particularly in predicting the direction contaminant plumes move from the 200 East Area). Three-dimensional transport modeling will require computer time on the order of days for a single realization, single contaminant simulation.

5.4.6 River Flow and Transport Module, MASS2

The River Flow and Transport Module will provide the capability to calculate the flow, sediment transport, and contaminant transport in the Columbia River system. The capability in the River Flow and Transport Module is provided by the legacy code MASS2 (Richmond et al. 1999a). MASS2 is a two-dimensional, depth-averaged model that provides the capability to simulate the lateral (bank-to-bank) variation of flow and contaminants. Stochastic variability of certain input parameters used by the River Flow and Transport Module will be generated by the ESP. Contaminant and water influx from groundwater will be input to the bed sediment layer in MASS2 using output from the GWDROP Data Translator. MASS2 will be modified to generate and output annual average concentrations of contaminants in the water column (dissolved and total sediment –sorbed) and in the bed sediments (pore water and total sediment-sorbed). The CRDROP data translator will use MASS2 outputs to archive concentration information for use by the impacts modules.

The MASS2 code, written in Fortran 90, will be enhanced to include the capability to simulate sediment transport, sediment-contaminant interaction (using K_d's), sediment-sorbed contaminant transport, and contaminant transport within the riverbed sediment layer. Routines from the existing ECEM code will be incorporated to model growth of aquatic plants and animals and solve for the contaminant concentration in each aquatic species. These routines will allow MASS2 to model the transport of contaminants downstream in the form of organic detritus.

The long-term simulations will be accomplished by using a library of previously computed seasonal flow fields and then using these flows in decoupled calculations for sediment and contaminant transport. Each run of the MASS2 code will handle all contaminants, all locations, and all time steps, but only a single realization.

Background contaminant levels from surface water inputs to the Columbia River in the portion of the river modeled (between Priest Rapids and McNary Dams) will be included in the model of the Columbia River system. This will support the ability of the SAC software to differentiate between background and Hanford contributions to impacts. A "Background" option will be available in the ESD to direct the SAC software to only simulate impacts arising from background contaminant levels in the Columbia River System (ignoring Hanford-originating contamination). A second complete simulation without the Background option would provide the total impact – Hanford-originating contaminants plus background. Post-processing of the results from these two analyses will estimate the incremental impact of Hanford-originating contaminants. River contaminant loading is the only background tracked in the Rev. 0 design; areal contamination over land surfaces (e.g., fallout from atmospheric testing prior to the Comprehensive Test Ban Treaty) within the model domain will not be tracked.

5.4.7 River Shore Environment Module, RIPSAC

The River Shore Environment Module will estimate contaminant concentrations at locations (specified in the ESD to support impacts calculations) along the river shore on the Hanford Site. These concentrations will be derived from groundwater concentrations at the aquifer-river boundary, as computed by the Groundwater Flow Module (CFEST96) and stored in the ECDA files by the GWDROP data translator.

Stochastic parameters (dilution factors – to seepage and to boundary layer sediments and cobbles and distribution coefficients for the sediment and soil) will be simulated in the ESP and passed to the River Shore Environment Module through data files.

The results of this modeling (concentrations in certain riparian media) will be stored in the ECDA files for use by the ecological, human, economic, and socio-cultural impacts modules. RIPSAC will be a new code, written in Fortran 95.

5.5 DATA TRANSLATORS

The three data translator modules to be used in the SAC (Rev. 0) calculations are all new codes that will be written in Fortran 95. Each code is designed to handle a single contaminant for single realization during a run; thus, they will be executed many times.

5.5.1 VZDROP Data Translator

The VZDROP data translator module will provide the capability to convert Vadose Zone Flow and Transport Module (STOMP code) contaminant mass release results into contaminant mass inputs for the Groundwater Transport Module (CFEST96 code).

5.5.2 GWDROP Data Translator

The GWDROP Data Translator Module will provide the capability to extract the following from Groundwater Transport Module results (CFEST96 code output):

- Groundwater contaminant concentrations for all times and locations required by the impacts modules that have a groundwater media for inclusion in the ECDA
- Groundwater mass flux rates with respect to time at all CFEST96 nodes adjacent to the Columbia River for use by the River Flow and Transport Module (MASS2).

5.5.3 CRDROP Data Translator

The CRDROP Data Translator Module will provide the capability to extract the following from River Flow and Transport Module results (MASS2 code output):

- River surface water contaminant concentrations for all times and locations required by the impacts modules that have a surface water media for inclusion in the ECDA

- River bottom pore water contaminant concentrations for all times and locations required by the impacts modules that have a river bottom pore water media for inclusion in the ECDA

- River bottom sediment contaminant concentrations for all times and locations required by the impacts modules that have a river bottom sediment media for inclusion in the ECDA.

5.6 IMPACTS MODULES

5.6.1 Ecological Impacts Module, ECEM

The ecological impacts model, ECEM, provides the capability to evaluate ecological-related risk metrics for Hanford Site-derived contaminants. The ECEM code will estimate risks and impacts to a wide variety of plant and animal species from various contaminated media, including groundwater, seep water, riparian soil, river-bottom sediment, river-bottom pore water, and surface water (river water). The ECEM will generate body tissue concentrations for all modeled species, as well as the dose or impact to all the species. The model calculates these values on an annual basis, assuming constant environmental conditions during the year.

The ECEM code is a pre-existing code written in Fortran that evaluates the impact metrics for all analytes at all locations in a stochastic manner in a single code execution. Analyte types handled include radionuclides and chemicals, both organic and nonorganic. Exposure pathways include dermal contact, ingestion, inhalation, and external radiation. Some minor functional changes will be made to the ECEM code, including the following:

- Modifying data input and output structures to access and output SAC data
- Adding the capability to evaluate impacts for a sequence of times
- Incorporating the common set of stochastic routines used throughout the SAC (Rev. 0).

5.6.2 Human Impacts Module, HUMAN

The human impacts model, HUMAN, provides the capability to evaluate human-related risk metrics for Hanford Site-derived contaminants. The HUMAN code will estimate health risks and impacts for humans from various contaminated media, including groundwater, river bottom sediment, seep water, and surface water (river water). The Human Impacts Module will also generate concentrations for fish, food crops, meat, milk, and other Native American cultural items (e.g., herbs, roots, berries) on an annual basis, assuming constant environmental conditions during the year.

The HUMAN code is a pre-existing code written in Fortran that evaluates the impact metrics for all analytes at all locations in a stochastic manner in a single code execution. Analyte types handled include radionuclides, chemical carcinogens, and noncarcinogenic hazardous chemicals.

Exposure pathways include dermal contact, ingestion, inhalation, and external radiation. Some minor functional changes will be made to the HUMAN code, including the following:

- Adding a population dose calculation for radioactive analytes
- Modifying data input and output structures to access and output SAC data
- Adding the capability to evaluate impacts for a sequence of times.

5.6.3 Economic Impacts Module, TCERM

The economic impacts model, TCERM, will calculate a number of metrics to evaluate the economic impacts from Hanford Site-derived contaminants. Economic impacts are evaluated as perturbations on the current economy of the Tri-Cities and surrounding counties. The general categories of economic impacts calculated will be the following:

- The change in the regional economy due to proscription or public avoidance of products such as field crops, vegetables, tree fruit and grapes, and livestock and dairy

- The economic value of public avoidance of recreational activities or the regulation of recreational activities, including fishing, water skiing, boating, and swimming

- The economic cost of alternative water supplies includes an estimate of the cost of water filtration or the annualized cost of a replacement water source.

The TCERM code is a new code to be written in Fortran 95. This code will evaluate the impact metrics for all analytes at all locations in a stochastic manner in a single code execution.

5.6.4 Socio-Cultural Impacts Module, CULTURE

The socio-cultural impacts model, CULTURE, calculates area metrics of use in evaluating the cultural impacts from Hanford Site-derived contaminants. The code will provide the following three general functions:

- Calculation of the area of contamination associated with groundwater plumes

- Generation of data for maps of locations where contamination concentrations exceed threshold values.

The CULTURE code is a new code to be written in Fortran 95. This code will evaluate the impact metrics for all analytes at all locations in a stochastic manner in a single code execution.

5.7 COMPUTER PLATFORM

The SAC (Rev. 0) will be a computationally demanding software system. Some of the legacy codes (e.g., CFEST96 and MASS2) are large scientific simulators that require massive computer memory and disk resources and long simulation times. Placing these resource and computationally intensive programs inside a stochastic framework leads to the need for a computer server system with several processors and substantial disk storage space dedicated to maintaining SAC software, controlling SAC simulations, and storing results.

A quad-processor Windows NT Server system with more than 100 gigabytes of hard disk space is being acquired to serve this function. SAC source code and development documentation will be maintained on this server using a configuration management system to preserve a traceable software development history and control software change. If future SAC revisions lead to a need for greater hardware capacity, this system will be preserved as the "development" platform while new hardware can be devoted to simulations. Additionally, a Dual Alpha Linux workstation is being acquired to provide a suitable environment for the MASS2 River Module to reside, which was developed and maintained under the Linux environment. The SAC Windows NT Server and the SAC Dual Alpha Linux Workstation will be housed in a protected computer laboratory facility, and configured for remote access and control by SAC developers and users.

Distributed computing will be essential to achieve reasonable total simulation times for the environmental release and transport modules. Use of the SAC Windows NT Server, the Dual Alpha Linux system, and several Windows NT Workstations to distribute the SAC simulations in a crude parallel fashion will be a part of the Rev. 0 effort. The SAC (Rev. 0) design includes consideration of distributed computing support by anticipating how calculations can be separated for independent, simultaneous simulation.

Relational database software is not incorporated into the SAC (Rev. 0) design. While relational databases offer some powerful features, these come with an overhead in the form of slower access and greater disk space usage per item of stored data. Instead, the SAC (Rev. 0) design philosophy is to use storage formats and structures developed specifically for the SAC that emphasize speed of data access and minimum disk storage space. An example of this is the highly structured, direct-access, binary format ECDA file specification.

6.0 TEST CASES FOR THE SYSTEM ASSESSMENT CAPABILITY (REV. 0) COMPUTER CODES

This section defines a suite of test cases to be performed for the SAC (Rev. 0) computer code. The suite of test cases will demonstrate operation of individual components of the overall suite of codes. The test cases are described in a general manner rather than specifying individual inputs for each parameter. Also provided is an indication of how a determination will be made whether a test was successful.

The SAC code development team will run more tests than those identified in this section. However, these tests will exercise the major features of the entire suite of code modules. Collectively, these tests provide a level of assurance that the SAC (Rev. 0) is operating properly. The term "multiple realizations" in this section means more than one realization. The exact number of realizations will depend on the specific test being run.

6.1 TEST CASES FOR THE INVENTORY MODULE

The Inventory Module defines the original amount of material available for environmental transport. This module has two broad purposes:

1. To account for annual analyte inputs, aggregating them to determine the inventory at each release location by waste type

2. Produce an inventory data set to account for the accumulated inventory (including radiological decay, as appropriate) to aid in mass balance and inventory accountability calculations.

The Inventory Module output is provided to the Vadose Zone Release Module.

6.1.1 Calculations for a Waste Stream

Visual examination of the output file and hand calculations will be used to confirm that analytes from a waste stream are distributed to a number of sites and are properly accounted for in the aggregated release site inventories.

A. Deterministic test (one realization).

   1. 4 analytes, 5 waste streams, 1 waste type, 10 years, 4 aggregate release locations.
   2. 4 analytes, 5 waste streams, 3 waste types, 50 years, 4 aggregate release locations.

B. Stochastic test (multiple realizations).

   1. 2 analytes, 5 waste streams, 1 waste type, 10 years, 4 aggregate release locations.
   2. 2 analytes, 3 waste streams, 3 waste types, 50 years, 4 aggregate release locations.

6.1.2 Uncertainty Algorithms in the Inventory Module

The stochastic inventory information of a release location is input to the Inventory Module as the distribution type (normal, for example) and the associated parameters (mean and standard deviation, for example). Minimum, median, maximum, mean, and the standard deviation of generated values will be examined to verify that the output inventory values are consistent with the defined input.

A. Stochastic test (multiple realizations).

1. 4 analytes, 1 waste stream, 1 waste type, 10 years, 1 aggregate release location.
2. 2 analytes, 3 waste streams, 3 waste types, 10 years, 4 aggregate release locations.

6.1.3 Mass Balance Algorithms

The Inventory Module monitors analyte mass for each calendar year. Annual inventories of release locations and offsite exports are also calculated. The computed mass balance for inventory will be compared with a spreadsheet-estimated total inventory for several cases.

A. Deterministic test (one realization).

1. 4 analytes, 1 waste stream, 1 waste type, 50 years, 1 aggregate release location.
2. 4 analytes, 5 waste streams, 1 waste type, 50 years, 4 aggregate release locations.

B. Stochastic tests (multiple realizations).

1. 4 analytes, 1 waste stream, 1 waste type, 50 years, 1 aggregate release location.
2. 4 analytes, 5 waste streams, 1 waste type, 50 years, 4 aggregate release locations.

6.1.4 Stress Testing

To stress test the Inventory Module, a large data set will be run through the code to examine whether it remains functional. The results will be visually inspected for reasonableness.

A. Stochastic (multiple realizations) - inventory input - 10 analytes, 400 waste streams, 6 waste types, 50 years, 10 aggregate release locations.

B. Stochastic (multiple realizations) - mass balance - 10 analytes, 400 waste streams, 6 waste types, 50 years, 10 aggregate release locations.

6.2 TEST CASES FOR THE RELEASE MODULE

The Vadose Zone Release Module estimates the release rates of analytes into the vadose zone. The Vadose Zone Release Module primarily uses data from the Inventory Module, but also uses data output from the Vadose Zone Flow and Transport Module STOMP. The data from STOMP are a result of modeled remediation actions moving analytes from one release point to another.

6.2.1 Release Rates by Waste Type

Testing release rates assures that the rates are calculated, as appropriate, by waste type and that they are routed to the correct aggregated release locations. Visual examination and spreadsheet calculations will be used to evaluate the test results.

A. Deterministic test (one realization).

1. 4 analytes, 10 release locations, 1 waste type, 50 years.
2. 2 analytes, 1 release location, 6 waste types, 50 years.

B. Stochastic (multiple realizations).

Same suite of tests as under Deterministic, but with stochastic Inventory input and Vadose Zone Release functions.

6.2.2 Mass Balance by Waste Type

The Vadose Zone Release Module needs to release, at most, the amount of inventory indicated by the Inventory Module. Mass balance tests using the same runs as in Section 6.2.1 will be conducted to ensure that the entire inventory is being tracked through the system. Spreadsheet calculations will be used to evaluate the test results.

6.2.3 Stress Testing

To stress test the release module, a large number of data input will be run through the code to ensure it remains functional. The results will be visually verified for reasonableness.

A. Stochastic (multiple realizations).

1. Release rates for 10 analytes, 10 release locations, 6 waste types, 1,000 years.
2. Mass balance for 10 analytes, 10 release locations, 6 waste types, 1,000 years.

6.3 TEST CASES FOR THE GROUNDWATER FLOW MODULE

As a legacy code, performance testing of the CFEST96 Flow Module has been conducted by the Groundwater Monitoring Project. The Groundwater Flow Module (CFEST96) provides a data file containing the time varying groundwater flow field at various points in the Hanford Site unconfined aquifer. Testing for this module will not be explicitly performed under the SAC development and testing effort. Operation and testing of the Groundwater Transport Module (see Section 6.6) will confirm operation of the data transfer needed by the Groundwater Flow Module.

6.4 TEST CASES FOR THE VADOSE ZONE FLOW AND TRANSPORT MODULES

The Vadose Zone Flow and Transport Module uses the Hanford Site legacy code STOMP (White and Oostrom 1996) to model the flow velocity of liquid effluents and the transport rate of analytes through the vadose zone. STOMP uses the contaminant release amounts, locations, and times generated as output by the Vadose Zone Release Module. The output of STOMP is primarily fed to the Groundwater Transport Module, but for some remediation cases is fed back to the Vadose Zone Release Module. The Vadose Zone Release Module receives STOMP feedback when remediation actions are modeled to result in analyte movements from one site location to another (e.g., contaminated soil removed from a CERCLA cleanup site and placed in ERDF). Test cases for the interaction of the STOMP and Vadose Zone Release Modules will be discussed in Section 6.5.

STOMP is a legacy code with its own quality assurance requirements. Prior to use for SAC (Rev. 0) output, the code will be tested according to its internal quality assurance requirements.

6.4.1 Transport Case Without a Remediation Action

The following test cases will follow the release for 100 years or until all material is released from the vadose zone.

A. Deterministic (one realization).

   1. 3 analytes (mobile, relatively mobile, immobile), 1 remediation action, 4 release locations, 100 years.

B. Stochastic (multiple realizations).

   1. 3 analytes (mobile, relatively mobile, immobile), 1 remediation action, 4 locations, 100 years.

6.4.2 Transport Case Involving Soil Removal from a Remediation Action

This test case is for the STOMP portion of the link with the Vadose Zone Release Module before information is forwarded. Results will be examined to assure that the modeled remediation action results in the appropriate mass balance movement.

A. Deterministic (one realization).

   1. 4 analytes, 1 remediation action, 4 locations, 1 year.

B. Stochastic (multiple realizations).

1. 4 analytes, 1 remediation action, 4 locations, 1 year.

6.5 TEST CASES FOR THE STOMP AND VADOSE ZONE RELEASE INTERACTIONS

Some remediation actions in the SAC (Rev. 0) will require moving contaminated media (e.g., groundwater or soil) from one Hanford Site location to another. The STOMP code halts its vadose zone transport calculations, subtracts a portion of the inventory, then feeds that inventory to the Vadose Zone Release Module.

6.5.1 Case Involving Remediation Actions

Testing will ensure that the remediation action is modeled at the appropriate time, contaminants are moved between sites, and that the proper mass balance is maintained. Spreadsheet calculations will be used to verify the results.

A. Deterministic (one realization).

1. 1 analyte, 1 waste type, 1 remediation action, 1 location, 10 years.
2. 4 analytes, 1 waste type, 2 remediation actions, 2 locations, 10 years.

B. Stochastic (multiple realizations).

1. 4 analytes, 1 waste type, 2 remediation actions, 2 locations, 10 years.
2. 4 analytes, 2 waste types, 4 remediation actions, 2 locations, 10 years.

6.5.2 Stress Testing

To stress test the Inventory Module, a large number of data input will be run through the code to ensure it remains functional. The results will be visually verified for reasonableness.

A. Deterministic (one realization).

1. 8 analytes, maximum number of waste types that will be subject to remediation actions, 20 remediation actions, 50 locations, 50 years.

B. Stochastic (multiple realizations).

1. 8 analytes, maximum number of waste types that will be subject to remediation actions, 20 remediation actions, 50 locations, 50 years.

6.6 TEST CASES FOR THE GROUNDWATER TRANSPORT MODULE

The Groundwater Transport Module uses the Hanford legacy code CFEST (CFEST 1996) to model the flow and transport of analytes through the unconfined aquifer. The CFEST software library was extensively tested (Cole et al. 1997). For the SAC (Rev. 0), CFEST uses the output of the Vadose Zone Flow and Transport Module and creates data used by the River Shore Environment Module and the River Flow and Transport Module. After reformatting in a data translator, CFEST output is also used by all impact modules. One new component to the CFEST-transport code developed for the SAC (Rev. 0) is modeling three-dimensional groundwater transport using a two-dimensional domain. This feature will be tested.

6.6.1 Extraction of Three-D Flow Data into Two-D Transport

The results of the three-analyte flows will be compared visually for reasonableness.

A. Deterministic (one realization).

1. 1 highly mobile, 1 moderately mobile, and 1 immobile analyte, 1 release location, 1,000 years.

2. 1 highly mobile, 1 moderately mobile, and 1 immobile analyte, 10 release locations, 100 years.

B. Stochastic.

1. 1 highly mobile analyte, 1 moderately mobile analyte, 1 release location, 1,000 years.
2. 1 highly mobile analyte, 1 moderately mobile analyte, 10 release locations, 100 years.

6.6.2 Stress Testing

No stress testing will be performed for the Groundwater Flow Module. Instead, interface issues for multiple realizations and multiple contaminants will be tested during integration testing (see Section 6.14).

6.7 TEST CASES FOR THE RIVER SHORE ENVIRONMENT MODULE

The River Shore Environment Module uses output from the groundwater transport model to estimate analyte concentrations in environmental media at points near the Columbia River. Contaminant concentrations will be calculated for soil and seep water on the shore above the waterline. These concentrations will be used by all of the impacts modules. These three calculations will require concentrations at different times and at different locations. Hand or spreadsheet calculations will verify the code output.

6.7.1 Concentration Calculations

The following tests will verify the calculation of concentrations.

A. Deterministic (one realization).

1. 1 analyte, seep water concentration, 1 year, 1 location.
2. 1 analyte, soil concentration, 1 year, 1 location.
3. 4 analytes (radionuclide and hazardous chemical), seep water concentration, 3 years, 5 locations.
4. 4 analytes, soil concentration, 3 years, 5 locations.

B. Stochastic (multiple realizations).

1. 1 analyte, seep water concentration, 1 year, 1 location.
2. 1 analyte, soil concentration, 1 year, 1 location.
3. 4 analytes (radionuclide and hazardous chemical), seep water concentration, 3 years, 5 locations.
4. 4 analytes, soil concentration, 3 years, 5 locations.

6.7.2 Stress Testing

To stress test the River Shore Environment Module, a large number of data input will be run through the code to ensure it remains functional. The results will be visually verified for reasonableness.

A. Stochastic (multiple realizations).

1. 10 analytes, 200 locations, 100 realizations, 1,000 years.

6.8 TEST CASES FOR THE RIVER FLOW AND TRANSPORT MODULE

The River Flow and Transport Module (MASS2 with ECEM) uses the riparian-region and river-bottom water flux, and the water concentration output of the Groundwater Transport Module (CFEST96). The incorporated ECEM code will use the results of MASS2 to calculate the uptake and transport of analytes due to biotic processes. The River Flow and Transport Module estimates analyte concentrations in two river water media and two river-bed media in the Columbia River. The water-column media results include analyte concentrations in river water and suspended sediment. The river-bed media results include concentrations in sediment pore water and settled sediment. The output of the River Flow and Transport Module will be used by all Impact Modules.

6.8.1 Biological Transport Calculation

These cases test the ECEM (biotic concentration) elements of the module. Verification of results will be accomplished using visual inspection and spreadsheet calculations.

A. Deterministic (one realization).

  1. 4 analytes, 5 locations, 2 years.

B. Stochastic (multiple realizations).

  1. 4 analytes, 5 locations, 5 years.

6.8.2 Analyte Transport

These cases test the contaminant transport elements of the module. Verification of results will be accomplished using visual inspection and spreadsheet calculations.

A. Deterministic (one realization).

  1. 4 analytes, 20 locations, 5 years.

B. Stochastic.

  1. 4 analytes, 20 locations, 5 years.

6.8.3 Stress Testing

To stress test the River Transport Module, a large number of data input will be run through the code to ensure it remains functional. The results will be visually verified for reasonableness.

The stress test will be run in stochastic mode and will incorporate 10 analytes, 2,000 locations, and 5 output times for 1,000 years.

6.9 TEST CASES FOR THE ECOLOGICAL IMPACTS MODULE

The Ecological Impacts Module uses a food web model to calculate the ecological risk to wildlife. Impact measures include the radiological dose (mrem/year), the body burden (concentration of contaminant in tissue) of analytes in animals and plants, and the ecological hazard quotient based on the body burden. The Ecological Impacts Module uses output from the River Shore Environment and River Flow Modules to estimate the impacts. Contaminants are subdivided into organic/nonorganic, radiological/stable, and species are subdivided into plant/animal, and terrestrial/aquatic.

6.9.1 Installation Test Case

The ECEM is a pre-existing code. The major test of the code will be to rerun a full analysis from a previous project after the code is integrated into the SAC (Rev. 0) framework. The test case will be a full stochastic run for multiple contaminants and locations that was performed for the CRCIA Project, Part I (DOE-RL 1998a).

6.9.2 Stress Test

To stress test the Ecological Impacts Module, a large number of data input will be run through the code to ensure it remains functional. The results will be visually verified for reasonableness. The installation test case will be expanded to multiple times and more locations for the stress test.

6.10 TEST CASES FOR THE HUMAN IMPACTS MODULE

The Human Impacts Module uses output from the River Shore Environment Module and the River Flow and Transport Module to estimate the risk to human receptors. A health impact metric is estimated for radionuclide and chemical exposures for an individual who may or may not use contaminated irrigation water. The risk metrics are dose and its subsequent risk of a latent cancer fatality for radionuclide exposures, and risk of either cancer or a noncarcinogenic health effect for hazardous chemicals.

6.10.1 Installation Test Case

The Human Impacts Module is a pre-existing code written in Fortran 77. The major test of the code will be to rerun a full analysis from a previous project after the code is integrated into the SAC (Rev. 0) framework. The test case will be a full stochastic run for multiple contaminants and locations that was performed for the CRCIA Project, Part I (DOE-RL 1998a).

6.10.2 Test Cases for Population Dose

A new feature on the Human Impacts Module for the SAC is the calculation of population dose. Results for population dose tests will be verified using spreadsheet calculations.

A. Deterministic (one realization).

   1. Population dose from 1 analyte, 1 time.
   2. Population dose from 2 analytes, 2 times.

B. Stochastic (multiple realizations).

   1. Population dose from 1 analyte, 1 time.
   2. Population dose from 2 analytes, 2 times.

6.10.3 Stress Test

To stress test the Human Impacts Module, a large number of data input will be run through the code to ensure it remains functional. The results will be visually verified for reasonableness. The installation test case will be expanded to multiple times and more locations for the stress test.

6.11 TEST CASES FOR THE ECONOMICS IMPACTS MODULE

The Economics Impacts Module uses the groundwater and surface water concentrations calculated by the Groundwater Transport Module and the River Flow and Transport Module to estimate the change in the regional economy. The study area is divided into four economic subregions. The annual change in the baseline economy that results from estimated contamination levels is the major code output.

High concentrations, in this section, mean that water concentrations are above the trigger levels used in the Economic Impacts Module. Trace concentrations mean that water concentrations are below trigger levels. Two trigger levels are used in the module: regulatory triggers and public avoidance triggers.

6.11.1 Economic Impacts Test Cases

Test cases will be run for all four economic subregions. Results will be verified with spreadsheet calculations for a limited number of years.

A. Deterministic (one realization).

1. 4 analytes, trace concentrations in groundwater and surface water, 5 times.

2. 4 analytes, trace concentrations in surface water, high concentrations in groundwater, 5 times.

3. 4 analytes, high concentrations (regulatory trigger) in groundwater and surface water, 5 times.

4. 4 analytes, high concentrations (public avoidance trigger) in groundwater and surface water, 5 times.

6.11.2 Stress Testing

To stress test the Economic Impacts Module, a large number of data input will be run through the code to ensure it remains functional. The results will be visually verified for reasonableness. The stress test will consist of mixed concentrations for 10 analytes, using 4 subregions, 100 realizations, and 200 time steps.

6.12 TEST CASES FOR THE CULTURAL IMPACTS MODULE

Determining socio-cultural impacts requires the output of a variety of upstream modules. Those modules and their data of relevance for the socio-cultural metrics are as follows:

- Groundwater Transport Module for analyte concentrations in groundwater
- River Flow and Transport Module for analyte concentrations in the surface water and sediment
- Ecological Module for locations of contaminated critters and vegetation.

The Socio-Cultural Impacts Module will identify locations where groundwater, surface water, river pore water, and river sediment concentrations exceed a specified threshold. The groundwater plume area, surface water plume area, and sediment surface area are also determined by the Socio-Cultural Impacts Module.

6.12.1 Calculation of Area of Contamination

The spatial extent of contamination can be determined for each individual analyte, as well as for all analytes combined. Hand or spreadsheet calculations will be used to verify results.

A. Deterministic tests (single realization).

1. 4 analytes (not all locations with high concentrations), individual extent in groundwater, 5 output times.

2. 4 analytes (not all locations with high concentrations), combined extent in groundwater, 5 output times.

B. Stochastic tests (multiple realizations).

1. 4 analytes (not all locations with high concentrations), individual extent in groundwater, 5 output times.

2. 4 analytes (not all locations with high concentrations), combined extent in groundwater, 5 output times.

6.12.2 Mapping the Spatial Extent of the Contamination

Maps of the spatial extent of contamination above a threshold (a different threshold applies to each media, such as groundwater, surface water, or sediment) will be generated. Hand or spreadsheet calculations will be used to verify results.

A. Deterministic tests (one realization).

1. Single analyte, 1 output time.
2. Single analyte, 5 output times.
3. 1 analytes, 1 output time.

B. Stochastic tests (multiple realizations).

1. Single analyte, 1 output time.
2. Single analyte, 5 output times.
3. 4 analytes, 1 output time.

6.13 TEST CASES FOR STOCHASTIC ROUTINES

A set of utility routines that generate stochastic values from specified statistical distributions will be provided for use in the individual codes in the SAC (Rev. 0). These pre-existing routines are written in Fortran 95.

6.13.1 Calculations Using Each Statistical Distribution

The statistical routines can generate values from 11 statistical distributions. Two types of tests will be conducted for each distribution.

A. Check the generated values for the correct range and appropriate summary statistics.
B. Check that error trapping for invalid data works properly.

6.13.2 Test of Dynamic Memory Allocation Techniques

A test will be run to verify that the dynamic memory-allocation techniques in the statistical routines work properly. The test will consist of a run that generates 1,000,000 values from each statistical distribution in a single run of the test code. Test success will be determined by visual inspection of summary output results.

6.14 INTEGRATION TESTS

The SAC (Rev. 0) consists of a suite of inter-related computer codes, most of which can also be executed in a stand-alone mode. The tests identified earlier in this section all deal with evaluating the performance of individual components of the suite of computer codes. Two tests will be conducted to evaluate the integration of all the components into a functioning systems code.

6.14.1 End-to-End Deterministic Calculations

Two tests will be performed for a single realization for the entire suite of computer codes - from inventory through all of the impacts modules. Mobile contaminants and relatively rapid release models (and associate waste types) will be used to ensure that information is passed through the entire capability.

A. Calculate results for a single mobile radioactive contaminant to determine whether data are correctly passed between code components for 150 years.

B. Calculate results for two mobile radioactive contaminants and one mobile chemical to determine whether data are correctly passed between code components for 150 years.

6.14.2 End-to-End Stochastic Calculation for a Single Mobile Contaminant

One test will be performed for multiple realizations for the entire suite of computer codes - from inventory through all of the impacts modules. This test will calculate results for five realizations for a single mobile radioactive contaminant to determine whether data are correctly passed between code components.

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